A

HAND-BOOK

OF

CHEMISTRY:

With Nineteen Illustrations.

BEING A PORTION OF

AN ANALYTICAL COMPENDIUM

OF THE

VARIOUS BRANCHES OF MEDICINE.

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PART III.

ORGANIC CHEMISTRY.

CHEMISTRY.

PRELIMINARY OBSERVATIONS.

PHYSICAL SCIENCE, in its most extended sense, comprises the two great divisions of *Natural History* and *Natural Philosophy*. The former includes Anatomy, Zoology, Botany, and Mineralogy; the latter embraces Chemistry, Geology, Physiology, and Mechanics.

CHEMISTRY may be defined to be the science which investigates the molecular changes of bodies; or more strictly, that which treats of the laws that relate to chemical attraction.

The whole material world is subject to *Force;* this it is which produces change in bodies. Two great opposing forces appear to exist,—Attraction and Repulsion : the *cause* of either is unknown, and purely speculative. Bodies are either solid, liquid, or gaseous, according as one or other of these two forces preponderate; thus, if the molecules of a body adhere with a force called *cohesion*, so that an exterior power is required to separate them, the body is termed a *solid;* if the cohesion is only such as to allow the particles to move upon each other, it is named a *liquid;* and if the particles are kept apart by a repulsive force (supposed to be Caloric), it is denominated a *gaseous* body.

Attraction comprises several species or subdivisions, as Cohesion, Chemical Attraction or Affinity, Gravitation, Capillarity, and Endosmose.

Cohesion.—This is the attraction between homogeneous particles. It is only exerted at insensible distances, the molecules never being in absolute contact, otherwise the property of *elasticity* could not exist, since this requires space for the molecules to move in.

Chemical Attraction or Affinity.—This is the attraction between heterogeneous particles. Like cohesion, it is exerted only at inappreciable distances; in other words, apparent contact must take place.

Gravitation.—This attractive force is displayed between masses, and at sensible distances. It gives weight to bodies, and it is the

cause of the tendency of bodies to fall towards the earth's centre. The great law of gravitation is, that " the attraction is directly as the quantity of matter, and inversely as the square of the distance." This law also regulates the movements of the solar system.

Capillarity.—This is the attraction exerted between liquids and fine tubes, called *capillary,* by which the liquid rises in the tube above the level of the surrounding liquid,—the height depending on the smallness of the diameter of the tube, being inversely to the latter. This is the cause of bodies being wetted when placed in contact with certain liquids, the latter being attracted to the surfaces of the former. Capillarity is not exerted equally between all solids and liquids; on the contrary, in some cases there is a positive repulsion, as between glass and mercury. The mere density of the liquid does not, however, modify the force.

Endosmose.—If a membrane be interposed between two liquids of different density, having an affinity for each other, they will intermix by passing through the pores of the membrane. But the rapidity with which the two currents are established, will be unequal, and will be modified by the membrane. The general law is, that *the stronger current is from the rarer to the denser liquid.* The term Endosmose is at present used to express this stronger current, no matter which direction it may take.

It is evidently a modification of Capillarity, though it is influenced by the relation subsisting between the membrane and the surface of the liquid. The essential conditions of endosmose are that the liquids should have an affinity for each other, and that one of them, at least, should have an affinity for the membrane.

Another physical force, frequently considered as a modification of Endosmose, is the *Diffusibility of Gases,* or the tendency of gases to commingle, even though differing in density, and separated by a porous partition. This is readily shown by taking a wide glass tube, and placing in its centre a septum of dry plaster of Paris, and then filling one side of it with oxygen, and the other with hydrogen. The two gases will penetrate the septum, though at very different rates; four cubic inches of hydrogen will pass into the oxygen side, while only one cubic inch of oxygen will pass in the other direction. According to Mr. Graham, the diffusibility of gases *is inversely as the square root of their densities;* thus, in the instance above given, the densities of hydrogen and oxygen are to each other as one is to sixteen, hence the diffusive power of the former is four times greater than that of the latter. This law is of great importance in nature, preventing the accumulation of noxious gases in any one spot, and regulating the intimate mixture of the constituents of the atmosphere.

In the process of respiration, the interchange between the oxygen of the air and the carbonic acid of the lungs is effected through

moist membranes, which considerably modifies their respective diffusibility, on account of their different solubility in water.

Under the present head we may most conveniently notice the subject of the physical constitution of the atmosphere and of other gases, and the method of ascertaining specific gravity.

PHYSICAL CONDITION OF THE ATMOSPHERE.—The proof that the atmosphere has weight is afforded in various ways, although we are not ordinarily sensible of it, as it surrounds us on every side, and is thus maintained in equilibrium. By weighing a large glass receiver before and after its contained air has been exhausted, we shall perceive an obvious difference in the weight. By placing the hand over the mouth of a small receiver, and exhausting the air from the interior, a painful pressure will be experienced from the superincumbent atmosphere. If a bladder be tied over an open-mouthed receiver, and the air be exhausted, the pressure will be sufficient to burst the bladder with a loud report. A similar result follows if a very thin glass receiver be exposed to the exhausting operation of the air-pump. All the above experiments prove that the atmosphere has weight; the *amount* of this weight is easily shown by the Torricellian experiment, which consists in filling a glass tube, closed at one end, forty or fifty inches long, with mercury, and plunging the open end in a vessel of the same liquid; the mercury will descend to about the level of thirty inches. It is kept at this height by the atmospheric pressure on the mercury in the basin. Now it is ascertained that a column of mercury thirty inches high and one inch square weighs about fifteen pounds; hence the inference that the atmosphere presses upon every square inch of the earth's surface with a weight equal to fifteen pounds. If water had been used in the above experiment, it would have risen to the height of thirty-four feet.

The *barometer* is but a modification of Torricelli's tube. It consists of a glass tube, a little over thirty inches long, closed at one extremity; it is filled with mercury, and then inverted so as to place the open end in a small cup of mercury; the pressure of the atmosphere upon the surface of the latter sustains the mercury in the column, as before mentioned. The use of the barometer as a *weather-glass* depends upon the fact that the atmospheric pressure varies at the same place; when it is greatest, the barometer will of course stand highest, and will indicate fair weather, and *vice versâ*.

As already remarked, gases are far more elastic than either solids or liquids. The elasticity of the air, and of gases generally, depends upon the degree of pressure to which they are subjected. By the law of Mariotte, *their density and elastic force are directly as the pressure, and inversely as the volume.* Thus, one hundred

cubic inches of air under any pressure, would expand to two hundred cubic inches if the pressure were reduced one-half, or contract to fifty cubic inches if the pressure were doubled.

As the height of the barometric column measures the pressure of the atmosphere, it follows that the higher we ascend, the lower will the column fall, on account of the diminished height, and consequently the weight, of the atmospheric column. Hence the barometer is a valuable instrument for measuring the height of mountains. It has been ascertained that a fall of one inch indicates an altitude of about 922 feet; this ratio is true only near the level of the sea, for as the height increases arithmetically, the pressure diminishes geometrically. At three miles elevation, the barometer stands at fifteen inches; at six miles it reaches 7·50 inches; at nine miles, 3·75 inches, &c. The whole height of the atmosphere is believed to be about 45 miles.

The action of the common water-pump and of the air-pump depends solely on atmospheric pressure; the elevation of the piston, in either case, producing a vacuum which is instantly filled by the pressure of the air forcing in the fluid.

SPECIFIC GRAVITY.—By this is meant the ratio of the weight of a body to its bulk, or the weight of a body compared with the weight of an equal bulk of some standard, which is received as unity. In solids and liquids this standard is pure water at the temperature of 60° F.

To find the specific gravity of a liquid, it is only requisite to weigh equal bulks of that liquid and water at the same temperature, and then divide the weight of the liquid by the weight of the water; the quotient will of course be greater or less than unity, as the liquid employed is heavier or lighter than water. Now, the simplest mode of weighing equal bulks is to weigh them in succession in the same vessel, taking care to have exactly the same quantity in both cases. Another method is to employ a solid body, as the stopple of a bottle, ascertain how much weight will sink it in the given liquid, and divide this by the weight required to sink it in water; this is obviously the same as ascertaining the weights of the relative bulks of the two, since a solid body always displaces *its own bulk* of a liquid.

To find the specific gravity of a solid.—Another method of finding the specific gravity of a solid body lighter than water, is first to weigh it in the air, then to attach to it a piece of metal heavy enough to sink it, and weigh the whole as before, and afterwards weigh the whole in water. The difference between the two last weighings gives the weight of the bulk of water equal to the whole mass. But we wish to find the weight of the bulk of water *equal to the light body:* this is done by subtracting from the last-mentioned weight the weight of a bulk of water equal to the piece of metal. Finally, we

divide the absolute weight of the light body in air by the weight of its equivalent bulk of water, as in ordinary cases, and the result will of course be less than unity.

The principle here is precisely the same as in the case of liquids: the rule being "to divide the weight of a given bulk of the body, by the weight of an equal bulk of water;" and the mode adopted is first to weigh the body in the air, then to weigh it in water; find out how much it loses by being weighed in water (which will express precisely the weight of an equal bulk of water), and then divide the first weight by this last, and the quotient will be the specific gravity. This rule is founded on the hydrostatic law, that when a solid is immersed in a fluid, it loses a portion of its weight exactly equal to the weight of the portion of fluid displaced; that is, equivalent to the weight of its own bulk of that fluid. If the solid be lighter than water, as in the case of cork, its specific gravity may be found by suspending a small glass funnel from a scale beam, and counterpoised so as to be just below the surface of the water; the lighter body is then to be thrown up under the funnel, which will, of course, destroy the equilibrium, and elevate the funnel. Ascertain how much weight will counteract the buoyancy of the light body, add this to its weight, and divide its weight by the sum; the quotient must, of course, be less than unity.

Hydrometers are instruments employed for ascertaining the specific gravity of liquids. They consist of hollow metallic balls, attached to a thin stem, and having a weight beneath, to keep it erect. The use of the hydrometer is very simple. The liquid to be tried is put into a narrow vessel, and the instrument floated in it. It is obvious that the denser the liquid, the higher will the hydrometer float; and *vice versâ;* the point on the graduated stem will then express the specific gravity.

To ascertain the specific gravity of gases, it is only requisite to fill a globe of known capacity with the gas, then to weigh it, and to divide the result by the weight of the same bulk of atmospheric air, which is the standard, or unity, for gases. It must also be remembered that the specific gravity of gases is influenced by their *purity,* their *hygrometric condition,* the degree of *pressure* to which they are subjected (their bulk being inversely as the pressure), and their *temperature,*

Fig. 1.

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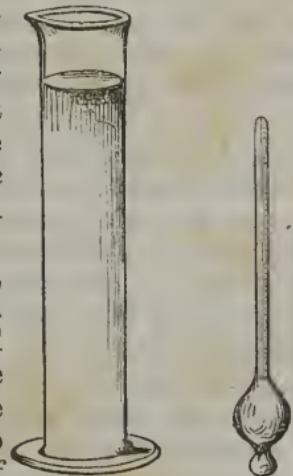
PART I.

IMPONDERABLE SUBSTANCES.

SECTION I.

CALORIC.

THE term *Heat* is used in two different senses : one signifying the sensation conveyed by a heated body; the other, the material *cause* of heat; this latter is called *caloric.* The effect of the union of caloric with ponderable matter is to communicate a repulsive property to its different molecules, overcoming its cohesion; and causing, successively, expansion, fusion, and vaporization. Caloric is usually spoken of under the two heads of *sensible*, or that which is evident to the thermometer, and *latent*, or that which is insensible to the thermometer. *Latent heat* may be illustrated by the following experiment :—Mix a pound of water at 174°, and a pound of water at 32° together; the temperature of the mixture will be the mean of the two, or 103°; but if a pound of snow or ice at 32° be used instead of the water at 32°, the resulting temperature will still be only 32°, but the ice will have melted. Hence, in this last experiment, as much heat has been rendered latent in the melting of the ice, as would have raised an equal weight of water *one hundred and forty-two degrees.* Again, if a vessel containing water be placed over the fire, the thermometer will indicate the constant increase in its temperature up to the boiling point, 212°; beyond this point, however, provided the steam escape, the successive portions of heat received by the liquid will be entirely insensible; that is, the additional caloric will be rendered latent. This latent caloric may, however, be proved to exist, or may be rendered *sensible*, by conducting the steam into cold water, when it will be found to raise the temperature of a quantity of water ten times heavier than itself, nearly one hundred degrees; or, if concentrated in one of these parts, the rise of temperature would be nearly one thousand degrees. Hence it follows, that as much heat is absorbed (rendered latent) in producing steam, as would raise the water of which it is composed one thousand degrees, or to about a red heat, if prevented from assuming the aeriform state.

The above law is universal. Whenever a solid body becomes

liquid, or whenever a liquid becomes gaseous, a quantity of heat disappears, or is rendered latent; and conversely, when a gaseous body is converted into a liquid, or a liquid into a solid, a corresponding degree of caloric is given out, or rendered free. The amount of latent heat varies much in different substances.

On this principle, the cold produced by the various *frigorific* mixtures is explained; thus a mixture of snow and salt produces a cold of zero, in consequence of the attraction between the salt and water producing liquefaction, and thereby rendering latent a large amount of caloric. A notable depression of temperature is also caused by a simple solution of certain salts in water, as of nitre, sal ammoniac, &c. A striking example of the reverse process, or the rendering latent heat sensible by condensation, is afforded in the slaking of lime by water; here, the large amount of heat evolved arises from the water passing into a solid state, in its combination with the lime. Another familiar instance is the rise of temperature usually experienced before a snow-storm, in consequence of the condensation of the vapour into snow, thus giving out its latent heat. Latent heat has hence been denominated the *heat of fluidity*, since it is necessary to maintain bodies in the fluid condition.

EFFECTS OF CALORIC.—EXPANSION.

Expansion is one of the first effects of caloric. It is caused by the repelling power produced by the caloric upon the particles of the body. As it is opposed to cohesion, it follows that those bodies are most expanded by heat which are least influenced by cohesion; thus gases are more expansible than liquids; and liquids more than solids.

Expansion in Solids.—This may be proved, by accurate measurement of them before and after heating;—by an accurately-fitted metallic plug and ring; if the plug be heated it will be too large for the ring;—the same is shown in heating the tire of a wheel before hooping it;—it is seen also in the elongation of the metallic bar of the *pyrometer*, by heat.

Of solid bodies, the *metals* are the most expansible. Metals are not equally expansible;—lead is most so; platinum the least. If a thin, straight bar of iron is firmly riveted to one of brass, and then exposed to heat, the brass being more dilatable than the iron, forces the bar in a curve, the convex side of which is brass; if it be artificially cooled, the brass contracts more than the iron, and the reverse of the above effect is produced. The supposed exception to the general law that solids expand by heat, in the case of clay, is only an apparent one; the contraction of this substance, as seen in Wedgwood's pyrometer, by the action of heat, is due to the shrinking produced by the loss of water. Beyond certain limits solids do not expand uniformly for equal increments of heat.

Expansion in Liquids.—Liquids differ from *fluids* in not being elastic;—they are more expansible than solids, as shown by placing an alcoholic and a mercurial thermometer in the same heated substance; the alcohol will rise much higher in the tube than the mercury. Liquids are not equally expansible. Nor is there any relation between their expansibility and their other properties, as density, &c. In being heated from 32° to 202°, alcohol expands $\frac{1}{9}$th of its bulk; water $\frac{1}{23}$d; mercury $\frac{1}{55}$th. The *rate* of expansion in liquids is not uniform,—it increases with equal increments of heat. There is one remarkable exception in the law that liquids expand by heat, in the case of water near the freezing point, which *expands* on being cooled below 39°—hence ice swims on water; this expansion is due to a new arrangement of its particles in the act of freezing.

Expansion of Gases.—Gases are much more expansible than either liquids or solids;—their *rate* of expansion is uniform, and is very nearly the same for all gases, being about 480th of the whole volume for every degree of Fahrenheit.

Fig. 2.

Thermometers are instruments for measuring sensible heat by means of the expansion and contractions of some fluid. *Sanctorio's* thermometer was the first invented;—it consisted of a glass tube terminating in a bulb, partially filled with air, and the open end plunged into some coloured liquid; the expansion or contraction of the contained air was marked by the depression or rise of the liquid. This thermometer is liable to two objections: the expansibility of air is too great to mark very considerable changes of temperature; and it is liable to be influenced by atmospheric pressure.

Leslie's differential thermometer is a modification of Sanctorio's air thermometer; it consists of a glass tube bent at right angles, and terminating in two bulbs. Both bulbs contain air, but the greater part of the tube is filled with a coloured fluid. So long as the same temperature acts upon both bulbs, no change can take place; but the slightest *difference* between the temperature of the two is detected by the movement of the liquid under the pressure of the air.
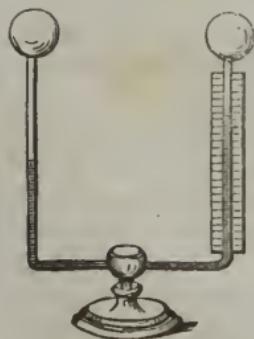
Fig. 3.

Liquids are much better suited than gases for thermometers; and of liquids, mercury is the best adapted, on account of the great range between its boiling point, 656°, and its freezing point, —40°; it is also very sensible to the action of heat; and its dilatations between 32° and 212° are nearly uniform. The

essential parts of a thermometer consist of a tube of a uniform small bore, terminating in a bulb; the ball and part of the tube are filled with mercury, and the air expelled by boiling the mercury, and then hermetically sealing the tube. The *boiling point* is ascertained by immersing the bulb in boiling water; the *freezing point*, by immersing it in melting ice. The distance between these two points is marked in various modes: in Fahrenheit's scale, the freezing point is marked 32°, and the boiling point, 212°; the intermediate divisions being 180 degrees. In the centigrade thermometer (Celsius'), the freezing point is zero, and the boiling point 100°. In Reaumur's, the freezing point is zero, and the boiling point 80°. As the ratio between these three scales is that of 180, 100, and 80, or 9, 5, 4, it is easy to reduce one to the other. The alcoholic thermometer is used when extremely low temperatures are to be measured, alcohol having never been frozen.

The expansibility of the air by heat is the cause of the phenomena of *winds*. The sun's rays falling nearly vertically over the equator, and very obliquely at the poles, produce a very unequal temperature at these points. The air at the equator becoming rarefied, rises and creates a partial vacuum, while the cold air from the poles will rush in to supply its place. In this way two currents are established towards the equator, one from the north, and one from the south pole, besides the upward current. In consequence, however, of the earth's motion upon her axis from west to east, the two currents just alluded to will take an oblique direction from east to west. These winds are called the *trade-winds*.

COMMUNICATION, OR TRANSFER OF HEAT.

Heat may be communicated to bodies in different modes:—by *contact*, as in the conduction of solids, and the circulation of liquids; by *radiation*, and by *reflection*.

Conduction of heat.—By this is meant the passage of heat from one particle of a body to another. This conducting power is very different in different bodies. Metals are the best conductors of heat, but not all equally so; gold is the best conductor, lead the worst; glass and porcelain are worse conductors than the metals. Liquids and gases are nearly destitute of conducting power, as may be shown by applying heat to the top of them; the mode of heating them is to apply the heat at the bottom, when instantly, there are two currents set in motion, the hot particles rising towards the surface, and the colder ones descending: this process is termed *circulation*, or *convection*.

Radiation of heat.—That mode by which heat is given off to some distance on all sides, by a heated body, is termed *radiation;* and the heat, *radiant heat*. Heat is emitted from a hot body in all directions, and in straight lines or radii, just as rays of light are

emitted from a luminous body. These calorific rays pass freely
through the air, or a vacuum, without sensibly affecting its tempera-
ture. When they fall upon the surface of a solid body, they may
be disposed of in three different ways :—1, they may be *reflected ;*
2, they may be *absorbed ;* or 3, they may pass through it, or be
transmitted. In the first and third cases, the temperature of the
body is unaffected ; in the second case, it is elevated.

The radiating power of bodies varies very much ; it depends
chiefly upon the nature of their surfaces, those which are rough and
soiled throwing out more heat than those which are smooth and
polished ; lamp-black is the best radiator, polished metals the worst.
Colour alone has no influence upon it.

Reflection of heat resembles reflection of light. It is familiarly
shown by holding a sheet of polished metal near the fire at an

Fig. 4.   Fig. 5.

angle ; the heat will be reflected
in the corresponding angle. It
may be better shown by placing
a red-hot iron ball in the focus of
a parabolic mirror ; the calorific
rays impinging on the mirror, will
be reflected, in straight lines ; and
if another similar mirror be pro-
perly adjusted, many feet distant,
these rays may be made to con-
verge again in its focus, so as to
affect a thermometer placed there,
or even to set fire to phosphorus.

It is a law, that the best radiators are the worst reflectors, and
vice versâ ; but the power of *absorbing* heat is in direct proportion
to the radiating power. The power of absorbing heat has been
thought to depend upon the *colour* of the substance ; but this has
been questioned. The laws of radiation explain the formation of
dew ; the surface of the ground being cooled down after sunset by
radiation, the aqueous vapour existing in the air is deposited in the
form of dew. If the night be cloudy, however, the rays of heat
are intercepted by the clouds which reflect them back, and hence
little or no dew is deposited. It is also well known, that the most
perfect radiators, such as grass, wood, leaves, &c., are the most
covered with dew, while a piece of polished metal, &c., would be
scarcely moistened. In the same manner also, the production of
the land and sea breezes of tropical islands is accounted for.

Transmission of heat.—By this is meant the passage of the ca-
lorific rays through certain media. Substances which transmit such
rays are called *transcalent,* or *diathermanous ;* it may easily be
shown by interposing a piece of plate glass between a red-hot body
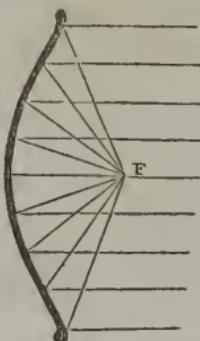
and a mirror; while all the rays of light will pass through the glass, many of the rays of heat will be arrested by it, so that but a very feeble effect is produced at the focus of the mirror. The only substance perfectly diathermanous is *rock salt;* other media, though entirely transparent, intercept the rays of heat to a greater or less extent. It has also been shown that radiant heat, like light, is capable of being *polarized*.

Vaporization.—This signifies the conversion of a solid or liquid into a vapour or gas, by heat. Vapours differ from gases only in being easily compressed into a liquid. Vaporization includes both *ebullition* and *evaporation*. In ebullition, the formation of the vapour is so rapid, that it rises to the surface in the form of bubbles, which then burst; the point at which this takes place is called the *boiling point*, and is always constant under the same circumstances; it varies very much for different liquids : thus, for water, it is 212° F. ; for alcohol, 172° ; for ether, 96° ; for sulphuric acid, 620° ; for mercury, 662°. The boiling point is chiefly influenced by the degree of pressure to which the liquid is subjected. On the earth's surface the atmosphere exerts a pressure upon every object of 15 pounds to every square inch; this force must be overcome by the elasticity of the vapour of a liquid before it can boil; hence, as the atmospheric pressure varies, the boiling point must equally vary ; hence water will boil at a much lower point on a mountain, or in a partially-exhausted receiver, than at 212°. So constant is the ratio between the depression of the boiling point and the diminution of the atmospheric pressure, that it forms a good method for ascertaining the height of mountains,—a depression of one degree being equivalent to an elevation of about 548 feet. Liquids boil, in vacuo, at a temperature of 140° lower than in the open air. The influence of diminished pressure in depressing the boiling point of a liquid, is shown in the experiment denominated the *culinary paradox*. A small flask of water is made to boil for a few minutes until the steam freely issues from the orifice; when it is firmly corked. On removing it from the heat, the ebullition of course ceases ; but it may be made to commence again by simply applying cold water to the upper part of the flask; the cold condensing the vapour, and thereby diminishing the pressure.

On the other hand, the boiling point may be much elevated by increasing the pressure. In this way, water may be prevented from boiling by the pressure of its own vapour—being confined in a strong metallic vessel. There is no limit to the degree to which water may be thus heated, provided the vessel be strong enough to bear the enormous pressure of the vapour thus generated. It is on this principle that the *high pressure* steam engine acts ; in it the steam is forced, both before and behind the piston, by means of sliding valves. In *low pressure* engines, a vacuum is created before

and behind the piston, by means of a condenser, so that the piston is driven into a vacuum, instead of against the pressure of the atmosphere. Other circumstances modifying ebullition are *the nature of the surface of the vessel*, and *the depth of the column of liquid.* The first of these depends upon the different degrees of attraction subsisting between the vessel and the liquid; the second, upon the increased pressure produced upon the lower stratum by a very tall column of liquid.

As already mentioned, a large amount of heat is rendered latent, by the production of steam.

A cubic inch of water, in becoming steam, under the ordinary pressure of the atmosphere, expands nearly into a cubic foot.

Evaporation differs from ebullition only in being a slower process, and not attended with the appearance of boiling; it occurs at common temperatures;—takes place in all fluids, and some solids, as camphor;—is much more rapid in such as have a low boiling point, as ether and alcohol. Evaporation is influenced by 1, extent of surface; 2, temperature:—heat is favourable to it; 3, hygrometric state of the atmosphere:—dryness favours it; 4, by a current of air; 5, by amount of pressure. The effect of removing the pressure is well seen by putting ether under a receiver, and removing the air; the evaporation is so rapid as to produce ebullition.

Cold is always produced by evaporation, in consequence of the amount of heat which is rendered latent. This is shown by placing a few drops of ether on the hand and exposing it to the air; or putting ether on the bulb of a thermometer, and noting the depression on the scale. By means of the cold produced by evaporation, water may be frozen by placing it over sulphuric acid in a receiver, and quickly exhausting the air. The same thing is also shown by Wollaston's *cryophorus*, or frost-carrier, which consists of a glass tube, of the figure represented in the cut. The bulb contains water,

Fig. 6.

the rest of the space being filled with aqueous vapour. The empty extremity being plunged into a mixture of snow and salt, the solidification of the vapour gives rise to such a quick evaporation from the surface of the water, that the latter freezes.

The temperature at which moisture is condensed from the air upon a cool surface, is called the *dew-point;* it varies according to the temperature and the amount of moisture present. Instruments

for ascertaining the dew-point are called *hygrometers*, the simplest of which is a silver cup containing water, which is to be cooled down till moisture is deposited on the exterior, and then the temperature indicated by a thermometer placed inside.

Specific heat, or capacity for heat.—By this is meant the ratio of the heat a body may contain, with the bulk or weight of the body. A simple experiment will prove that different bodies, though exhibiting the same *apparent* temperatures, contain, in reality, very different amounts of heat. Thus, in mixing a pound of mercury at 162°, with a pound of water at 100°, the temperature of the mixture will be 102°; here, the mercury, by losing 60°, raises the water 2°. But if the water be at 162°, and the mercury at 100°, the temperature of the mixture will be 160°; in this case, the water, by losing 2°, raises the mercury 60°. From this it appears that the same heat which would raise water 2°, will raise an equal weight of mercury 60°, being in the ratio of 1 to 30. By a similar experiment in oil and water, it is found that the ratio between them is that of 2 to 1.

There are three different modes of ascertaining the specific heat of various substances. The first is by observing the quantity of ice melted by a given weight of the substance heated to a particular temperature; the second, by noting the time which the heated body requires to cool down through a certain number of degrees; the third is the method of mixture, just pointed out, and is the one usually preferred.

The spheroidal condition.—By this is meant the peculiar shape which water and other liquids will assume when thrown upon a red-hot smooth metallic surface. Instead of immediately escaping as vapour, the liquid will play upon the surface in spheroidal globules until the temperature is reduced to 212°, when it will suddenly explode into vapour. This is probably the cause of many steam boiler explosions; becoming red-hot, the water assumes the spheroidal state, and no steam is generated; but on suddenly cooling it down by the admission of more water, instantaneous explosion ensues.

Means of producing heat.—It will suffice here merely to mention them; viz., lenses and mirrors, percussion, friction, condensation, combination, electricity, galvanism, fermentation, and vitality.

SECTION II.

LIGHT.

THERE are two theories of Light: one—the Newtonian—is that it consists of infinitely small particles, emitted by luminous bodies;

the other, that of Descartes,—that it depends upon undulations transmitted through a highly-elastic medium of extreme tenuity, called an *ether*, just as sound is produced by the undulations of the atmosphere.

Light travels in straight lines in every direction, with extreme rapidity; it occupies about eight minutes in coming from the sun to the earth, which is at the rate of 200,000 miles in a second.

When a ray of light falls on a plane surface, it may either be absorbed, or reflected, or it may be transmitted through it.

By *reflection*, is meant that property which causes a ray of light, striking upon a bright surface, to be thrown back, at an angle which is always equal to the angle of incidence.

Refraction of light, is where a ray, in passing from one medium into another of different density, is bent from its straight line. Where the ray passes from a rarer to a denser medium, it is refracted *towards* a line perpendicular to the surface of the latter; but when it passes from a denser to a rarer medium, it is bent *from* a line perpendicular to the surface of the denser substance. Different substances possess different degrees of refractive power; generally speaking, the densest substance refracts most; the same is true also of combustible substances.

White light is compound,—that is, it is made up of different coloured rays, as may be proved by admitting a ray of light through a small aperture into a dark room, and interposing a glass prism; it will not only be refracted from its straight course, but will be decomposed into seven differently-coloured spaces, forming a figure termed the *solar spectrum*. The upper part of the spectrum is red; the lower, violet; the intermediate portion, commencing with the violet, being indigo, blue, green, yellow, and orange, all gradually shading off into each other. These were termed by Newton the *prismatic* or *primary* colours, from the impression that they were the elements of white light.

Fig. 7.

Brewster's opinion, which is rather the received one at present, is, that there are only *three* primary colours, viz., *blue, yellow,* and *red;* and that when these are mixed in definite proportions, white light will result; but that when any of them is in excess, then the effect of *colour* will be produced. The colours of natural objects are supposed to result from the surfaces of these bodies absorbing certain rays, and reflecting or transmitting others; thus an object appears *red*, because it absorbs a portion of the yellow and the blue rays composing the white light which falls upon it, while it reflects the red rays; it appears *white* when it reflects all the rays, and *black* when it absorbs them all.
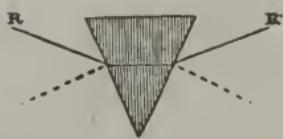
The greatest *illuminating* power of the spectrum is about its middle, or rather, between the yellow and green; the greatest *heating* power is in the red space or beyond it, varying with the kind of prism used; the *deoxidizing* power is greatest in the violet space, or just beyond it. The red ray is the least refrangible; the violet ray the most so.

The *chemical* effects of light are well marked; thus a mixture of chlorine and hydrogen may be kept for any length of time in the dark; but under the influence of light, a combination soon ensues; so the blackening and the decomposition of the salts of silver occur rapidly in the light. But the most remarkable chemical effect produced by light is upon the leaves of growing plants, which then possess the property of decomposing the carbonic acid of the air, appropriating the carbon to themselves, and giving out the oxygen.

Rays of light are *absorbed* much more by some bodies than by others. As a general rule those which absorb radiant heat most, are the best absorbers of light. Colour appears to exercise a great degree of influence over it; dark-coloured substances, for this reason become sooner heated than light-coloured ones.

A ray of light when made to pass through certain kinds of crystals, as Iceland spar, is divided into two, one of which is refracted in the ordinary way, the other taking an extraordinary direction; this is denominated *double refraction*.

Another property of light is its capability of *polarization*.

SECTION III.

ELECTRICITY.

THE term *electricity* is derived from the Greek word signifying *amber*, since this is the substance in which electrical excitement was first discovered. Electrical excitement may be produced by rubbing glass, amber, or resin, which will then attract light bodies. There are two varieties or states of electricity, the *vitreous*, or that excited in glass, which is also called *positive* electricity, and the *resinous*, or that excited in resins, called also *negative* electricity. The difference between these may be easily shown by suspending a light pith-ball, or a feather, by means of a thread of silk; then on exciting a dry glass tube and presenting it to it, the body will be attracted, but after a few moments it will be repelled, in consequence of receiving electricity from the glass tube; if now, a stick of resin properly excited be presented to it, it will be attracted; but after

touching the resin and receiving some of its electricity, it will soon be repelled by it; but on the other hand, attracted by the glass. This experiment establishes the law "that bodies similarly electrified, repel each other, but dissimilarly electrified they attract." Electricians divide bodies into *electrics*, or *non-conductors*, as glass, resin, sulphur, &c., and *non-electrics* or *conductors*, as the metals, water, &c. The essential parts of the *electrical machine*, are, 1, the *electric*, which is usually a glass cylinder or plate, contrived so as to be capable of turning by means of a handle; 2, the *rubber*, which is a stuffed cushion covered with an amalgam of tin, zinc, and mercury, against which the electric is rubbed; 3, the *prime conductor*, which is a metallic cylinder armed with a number of points for the more perfect collection of the electricity. Both cushion and conductor should be *insulated*, that is, supported on a pedestal of glass which is a non-conductor. The cylinder, as it turns, becomes charged with positive (vitreous) electricity, by friction against the cushion, and is as quickly discharged, by the rows of points, into the prime conductor, which, as it is insulated, thus acquires a charge of posi-

Fig. 8.
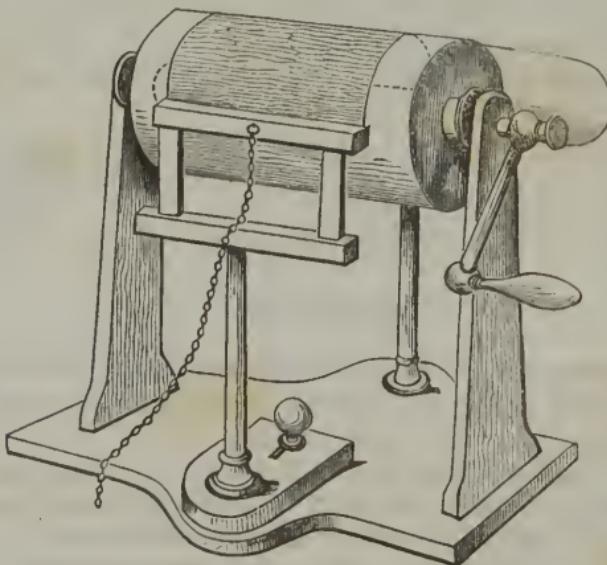
tive electricity, which it will yield up on contact with any body, with a peculiar noise and spark. The maximum effect is produced when the rubber is made to communicate with the earth by means of a chain. If *negative* electricity be wanted, the conductor must be made to communicate with the earth, and the rubber insulated, the electricity being drawn from the latter.

The *Leyden jar* is an instrument for *accumulating* electricity. It depends on the principle that a large amount of the two different sorts of electricity may reside on the two surfaces without any tendency to equilibrium, on account of the non-conducting power of the glass. It consists of a thin glass jar coated on both sides with tin foil to within a few inches of the top; a wire, terminating in a metallic knob, communicates with the interior coating. When the outside coating is connected with the earth, and the knob placed near the prime conductor of the machine, the inner and outer surfaces become respectively positive and negative. If, now, the two coatings be made to connect by means of a bent wire, the equilibrium is restored, a bright spark is perceived, along with a sharp snap, and if the body be interposed, the *electric shock* is felt.

Fig. 9.

The *electric battery* is only a great number of such jars connected together by their inner and outer coatings respectively; the whole then act as one very large jar, by which great extent of surface and an enormous accumulation of electricity are gained; the whole may be discharged at the same moment, and the effect is, of course, exceedingly powerful.

By *electrical induction* is meant the power which an electrified body has to produce an opposite electric condition in a contiguous body; it is by virtue of this law, that when an electrified body, as a glass tube previously rubbed, approaches a light body, as a feather or pith-ball, it immediately *attracts* it, having first *induced* in it an opposite electrical state. A series of globes suspended by silk threads, in the manner represented, will each become electric by *induction*, when a charged body is brought near the end of the series. The positive and negative signs are intended to represent the states.

Fig. 10.

The electrical state of the atmosphere is liable to disturbance: experiment has shown that the higher regions of the air are usually in a positive state: in cloudy and stormy weather, the clouds near the surface often appear in a negative state. In a thunder-storm, the cloud and the earth may be considered as representing the two coatings of the Leyden jar, differently electrified,—and the intervening air, the bad conducting glass. The dangerous effects of lightning are much lessened by the use of *lightning rods*, which are

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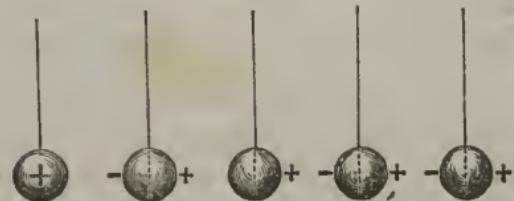
metallic conductors terminating above in a point, and below passing to a considerable depth into the earth. The object of the *pointed* extremity is to conduct off the discharge silently; a blunt extremity would give rise to a spark, and perhaps a shock, which might be unsafe; this may be easily shown by experiment with the electrical machine.

Fig. 11.

Electrometers and *electroscopes* are instruments for indicating, or measuring the electrical intensity. The most simple one is that named the *gold leaf electrometer*; it consists of a pair of gold leaves suspended from the top of a bell-jar and communicating above with a metallic cap. When an electrified body is brought near the cap, its presence is immediately detected by the divergence of the gold leaves. There are other electrometers known by the names of *quadrant electrometer, torsion electrometer, balance electrometer*, &c.

Two theories of electricity have long been maintained. One is the *theory of two fluids*, which supposes two distinct kinds of electricity, and that these exist in all substances, the one named *vitreous*, because developed in glass, the other *resinous*, because manifested in resins; that these two fluids neutralized each other, and preserved an equilibrium in bodies at rest; but that when this equilibrium was disturbed by friction, &c., one or other kind of electricity was displayed. The other is *the theory of a single fluid*, or that of Franklin. It supposes all bodies to possess it in a certain amount, and that their equilibrium is constantly liable to disturbance by friction, &c.; that when it is in excess, it is *positively* excited; when in deficiency, it is *negatively* excited; and that there is a constant tendency to an equilibrium.

SECTION IV.

GALVANISM, OR VOLTAIC ELECTRICITY.

When two solid bodies, as two pieces of metal, are plunged into a liquid capable of acting upon them unequally, the electric equilibrium is disturbed, the one acquiring the positive condition, and the other the negative. Thus, a piece of zinc and a piece of copper, placed in a dilute solution of sulphuric acid, will cause such a disturbance of the electrical equilibrium; the zinc being the metal most attacked, becomes *negative*, while the copper becomes *positive*; and in making a communication between the two, an electrical current is set in motion. The intensity of the electricity thus developed is extremely feeble; but by arranging a number of single pairs of metals with the intervention of a fluid, or moistened cloth, in such a manner that the direction of the current shall be the same

in each, the intensity will be very much augmented; upon this principle the *Pile of Volta* and the *Crown of Cups* are contrived.

The *Voltaic pile* consists of a number of small plates of zinc and copper arranged in a pile, each pair being separated by means of a piece of cloth moistened with sulphuric acid, as seen by the figure. If the two terminal plates be now touched with wet hands, a prolonged electric shock will be experienced, the intensity of which may be increased to almost any extent, by simply increasing the number of plates.

Fig. 12.

The *Crown of Cups* is similar in principle, though different in form; it consists of any number of cups or glasses, arranged in a row or circle, each containing a piece of copper and zinc, and some dilute acid. The copper of the first cup is connected with the zinc of the second; the copper of the second, with the zinc of

the third, and so on; on establishing a communication between the first and last plates, a discharge takes place as before.

Whenever such an arrangement consists merely of a single pair of conductors, and an interposed liquid, it is called a *simple circuit;* when two or more alternations are concerned,

Fig. 13.

it is a *compound circuit;* but however complex the apparatus may be, the principle is, in all cases, precisely the same. The disturbance of the equilibrium may be considered as commencing at the surface of the most oxidizable metal, and to be propagated through the liquid to the least oxidizable metal; hence, when insulated, the zinc end of the series is always negative, and the copper end positive. When the two extremities are joined, the current continues to pass from the copper to the zinc; so that in fact, we may consider that there are two currents: one, *in* the battery, passing from the zinc to the copper; the other *out* of the battery, going from the copper to the zinc, as shown by the arrows in the preceding figure.

Cruikshank's trough is a modification of Volta's pile; it consists of numerous pairs of zinc and copper plates soldered together, and cemented watertight into a mahogany trough, which thus becomes divided
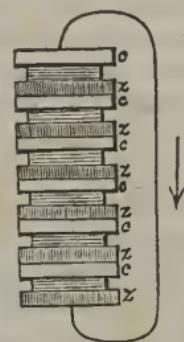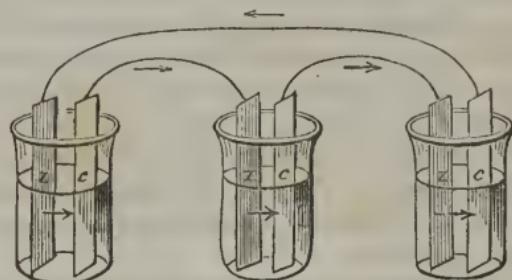
Fig. 14.
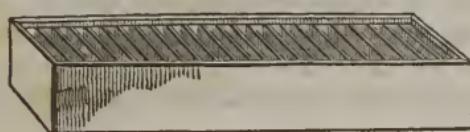
into a series of cells or compartments, capable of receiving the exciting liquid. This apparatus is well adapted to exhibit effects of tension, and give shocks.

The *quantity* of electricity set free, is to be distinguished from its *tension ;* the first is measured by its *chemical* effects—particularly the power of decomposition, and depends on the surface; the last, by its power of overcoming obstacles, and passing through imperfect conductors ; it depends on the number of plates. The energy of a Voltaic current is measured by the deflection of a magnetic needle.

Different theories as to the nature and cause of galvanism.—Galvani supposed it to be developed in the animal upon which he was experimenting, and that the metals served merely as conductors ; Volta, on the other hand, supposed it to be developed by the contact of dissimilar metals. Subsequently, Faraday brought forward the theory of *chemical action*, which is now most generally adopted.

The most important effect produced by galvanism, is that of the decomposition of compound bodies. It was by means of this agent that Sir H. Davy made the discovery of the metals of the alkalies. When compound bodies in the fluid state are traversed by a galvanic circuit, a decomposition usually takes place according to a uniform and constant rule ; certain elements, as oxygen, chlorine, iodine, acids, &c., appearing at the positive or *zinc* end of the battery, and others, as hydrogen, the metals, &c., at the *copper* or negative end. Hence the division of bodies by chemists according to their electrical habitudes ; those which go to the positive pole being called *electro-negative*,—at the head of which stands oxygen ; and those which go to the negative pole being called *electro-positive*, of which, hydrogen is the first.

The *electrodes* or *poles* of a battery are the points of the circuit (usually the extremities) where the electrical phenomena are manifested. The decomposition of a fluid by galvanic action is termed *electrolysis ;* and the liquids which are capable of being thus acted on are named *electrolytes*.

A *constant* battery is one which preserves its power of action for an indefinite time. The common zinc and copper battery soon loses its power, from the fact that the sulphate of zinc gradually formed is also gradually decomposed by the hydrogen constantly evolved at the copper plate, on which the reduced metallic zinc becomes deposited, converting, as it were, the copper into a zinc plate. Various constant batteries are in use, as Daniel's, Children's, Grove's, &c.

Magnetic effects of galvanism.—Among the effects of galvanism, its influence over the magnet is very remarkable. Although the fact had been long known that electricity was capable of inducing and destroying magnetism, as witnessed in the effects of lightning on the compass-needle, it was not until the year 1819 that the laws of these phenomena were established by Œrsted, and the science of

electro-magnetism truly developed. It is found that if a galvanic current be set in motion near a magnetic needle, the latter will arrange itself across the current, so that its axis may be perpendicular to the wire.

To ascertain the direction of a current, or the deflection of a needle, the following simple plan will assist: let a person suppose his own body to be the conducting wire, and to be placed in its position; then, while looking at the marked pole, and the current is passing from his head to his feet, it will be deflected to the right hand; if from his feet to his head, to the left hand.

When an electric current is passed at right angles to a piece of iron or steel, the latter acquires magnetic polarity, either temporary or permanent; the direction of the current determining the position of the poles. This effect is very much increased by causing the current to circulate a number of times around the bar, which soon acquires extraordinary magnetic power. A piece of soft iron in the form of a horseshoe, surrounded thus by a coil of copper wire, insulated by being covered with silk, may be made to become so highly magnetic, simply by connecting the two ends of the iron with a small battery of a single pair of plates, as to be capable of sustaining a very heavy weight.

Fig. 15.

As electricity can produce a magnetic influence, in the same manner it is found that magnetism can call into activity electric currents. If the two extremities of the coil of the electro-magnet just described, be connected with a galvanoscope, and the iron magnetized by the application of a steel horseshoe magnet to the ends of the bar, a momentary current will be developed in the wire, and pointed out by the movement of the needle. On removing the magnet, whereby the polarity of the iron is at once destroyed, a second current will become apparent, but in the opposite direction to that of the first. By using a very powerful steel magnet, surrounding its iron keeper or armature with a very long coil of wire, and then making the armature itself rotate in front of the faces of the magnet, so that its induced polarity shall be rapidly reversed, magneto-electric currents may be produced of such intensity as to give bright sparks, and powerful shocks, and exhibit all the phenomena of voltaic electricity. The accompanying figure represents such an arrangement.—There is a great variety of form in electro-magnetic machinery; but in all,

Fig. 16.

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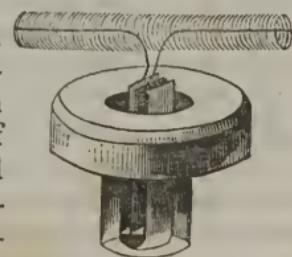
even the most complicated, the *essential principle* is the same, viz. : the development of an electrical current by magnetic action.

The earth is supposed to be a great magnet, having electric circles traversing it at right angles from east to west, and having its north and south pole corresponding to its respective geographical poles; hence the north pole of a magnet should really be considered its south pole, and *vice versâ*, because opposite poles attract. For this reason the poles of a magnet are now often named the *marked* and *unmarked* poles.

It has lately been announced by Faraday, that oxygen gas is highly magnetic.

PART II.

INORGANIC CHEMISTRY.

CHAPTER I.

PRELIMINARY REMARKS ON CHEMICAL NOMENCLATURE, AFFINITY, ETC.

MATERIAL substances are divided by the chemist into *simple* or *elementary*, and *compound*. The simple bodies are such as have as yet resisted all efforts to decompose them. Compound bodies are those that may be resolved into two or more elements. It is possible that some bodies at present regarded as elementary may hereafter prove to be compound, as was the case with the alkalies.

The number of simple bodies recognised by chemists at the present day is sixty-two; of these, forty-nine belong to the class of metals, and thirteen to the class of non-metallic bodies.

CHEMICAL NOMENCLATURE.

In the formation of a chemical nomenclature, the names given to many of the elements were expressive of some of their striking properties :—thus *oxygen*, from two Greek words, signifying to produce an acid, from the idea that oxygen was the sole acidifying principle; *hydrogen*, from two words signifying to produce water;— others again derived their names from words expressive of their *colour*, as chlorine, iodine, cyanogen, &c. The compounds of oxygen were named *oxides* or *acids*, according as they do, or do not possess acidity. Acids derive their name from the substance acidified by the oxygen, by the termination in *ic ;* thus sulphur*ic*, carbon*ic*, phosphor*ic*, &c. Should the substance be capable of forming more than one acid, the name of that containing least oxygen is made to terminate in *ous*, as sulphur*ous*, nitr*ous*, &c. When the same substance forms several acids with oxygen, the Greek preposition *hypo*

is generally prefixed to express the relative quantity of oxygen; thus, *hypo*nitrous and *hypo*sulphuric indicate acids containing less oxygen than nitrous and sulphuric acids respectively; sometimes the particle *per* is prefixed to express the highest amount of oxygen, as *per*chloric acid.

The nomenclature of the *salts* is made to depend on the termination of their acid; thus, acids ending in *ous* form salts terminating in *ite*, as sulph*ite*, nitr*ite*, from sulphur*ous* and nitr*ous* acids; acids ending in *ic*, as sulphur*ic* or nitr*ic*, form salts terminating in *ate*, as sulph*ate* and nitr*ate*.

The termination of names of compound bodies is directed chiefly by analogy; thus the non-acid compounds of chlorine, iodine, bromine and fluorine, from the analogy of these bodies with oxygen, are named chlor*ides*, brom*ides*, iod*ides*, &c. The compounds of the inflammables terminate generally in *uret*, as carb*uret*, sulph*uret*, phosph*uret*, &c.

Different *oxides* of the same metal are distinguished by the numerals prefixed. The oxide containing a single equivalent of the metal and oxygen is named *prot*oxide; that containing the greatest amount of oxygen, the *per*oxide; the intermediate oxides are expressed by Latin numerals, as the *deut*oxide or *bin*oxide, *ter*oxide or *trit*oxide, &c.; the Greek numerals, *dis*, *tris*, &c., prefixed, denote oxides containing one equivalent of oxygen with *two*, *three*, or *more* equivalents of the metal; thus, the *di*oxide of copper. A *sub*oxide signifies an oxide containing less oxygen than a protoxide.

The same system is also extended to salts, where there is more than one formed by an acid with the same base. When the salt is *neutral* it is simply named according to the nature of the acid, as sulphate, or nitrite; if it contains two equivalents of the acid, it is named a *bi*sulphate, or a *bi*carbonate, &c. If it contains two equivalents of the base, it is named a *di*sulphate, &c. The term *sesqui*, (one and a half), is used to indicate the relation of 1 to $1\frac{1}{2}$, or 2 to 3, as in the sesquioxide of iron, a compound consisting of two eq. of iron and three of oxygen.

The generic part of the name of a compound is usually formed from that ingredient which is the most electro-negative; thus in compounds formed between oxygen, chlorine, iodine and sulphur, we say oxide of chlorine, chloride of iodine, iodide of sulphur; and not chloride of oxygen, iodide of chlorine, or sulphuret of iodine.

It is often, however, very difficult to apply appropriate names to the highly-complex bodies of the organic world; in which cases more particularly, the use of chemical signs or *symbols* becomes very advantageous, as will be briefly shown.

Every elementary substance is designated by the first letter of its Latin name, in capital, or by the first letter conjoined with a second small one most characteristic, since the names of many bodies begin

alike; thus, Aluminium, Al.; Arsenic, As.; Bromine, Br.; Boron, B.; Barium, Ba.; Carbon, C.; Chlorine, Cl.; Hydrogen, H.; Iodine, I.; Iron (ferrum), Fe.; &c. It is always understood that these symbols express *one equivalent of the substance.*

Combination between bodies is expressed by a mere juxtaposition of the symbols, or sometimes by interposing the sign $+$: thus water is expressed by HO, or $H+O$; hydrochloric acid, by $H\,Cl$, or $H+Cl$; protoxide of iron, by FeO, or $Fe+O$.

When more than one equivalent is intended, the number is either prefixed to the symbol, or else placed after it: thus, sulphuric acid, $S+3O$, or SO^3, or SO_3; hyposulphuric acid, $2S+5O$, or S^2O^4, or S_2O_5, &c. Sometimes abbreviations are made use of: thus, two equivalents of a substance are indicated by the symbol with a short line drawn through or below it; an equivalent of oxygen is signified by a dot, and one of sulphur by a comma, thus sesquioxide of iron, $\overset{..}{Fe}$.; bisulphuret of carbon, $\overset{..}{C}$, instead of CS_2.

A number placed before a compound multiplies all that follows in that compound; thus, the formula expressing three equivalents of the sulphate of the sesquioxide of iron is written $3\,(Fe_2O_3+3SO_3)$.

CHEMICAL AFFINITY.

This is the attraction existing between the heterogeneous elements of compound bodies, whilst *cohesion* is the attraction between homogeneous particles. In water and sulphuric acid, for instance, both compound bodies, the chemical affinity is exerted between the oxygen and hydrogen in the one case, and between the sulphur and oxygen in the other. The most simple case of chemical affinity is where two bodies unite together to form a third body; as copper and zinc forming brass; sulphuric acid and soda to form sulphate of soda.

The second case of affinity, called *single elective attraction,* is where two heterogeneous bodies having united together to form a compound, another body, being blended with them in solution, unites with one of the former; for example, potash being added to a solution of sulphate of magnesia, unites with the sulphuric acid, and precipitates the magnesia; water on being added to the tincture of camphor (camphor and alcohol), will unite with the alcohol and precipitate the camphor.

The third case of affinity, called *double elective attraction,* is where two compound bodies, on being intimately mingled, undergo a mutual decomposition, the four components interchanging places: thus, a solution of acetate of lead and a solution of sulphate of zinc, on being mixed, give rise to an acetate of zinc and a sulphate of lead.

The *fourth* case of affinity is where two bodies being in combination, a third, on being added in excess, combines with both the

others; thus, ammonia being added to the solution of sulphate of copper, at first throws down the oxide of copper; but on continuing to add the ammonia, the excess combines with the precipitated oxide, which is then redissolved.

Circumstances modifying chemical affinity.—One of these is *heat;* thus, by heating mercury in the air, it will combine with oxygen; and by simply increasing the temperature, it will separate again from the oxygen. Another modifying agent is *solution:* many substances which, when in the dry state, evince no tendency to unite, when moistened or dissolved, exhibit a powerful affinity; thus tartaric acid and a carbonated alkali may be kept together, if dry, without any union; but if moistened, effervescence takes place. *Mechanical division* also greatly promotes chemical action, by overcoming cohesion, as may be seen by the action of nitric acid on a brass ball being far less violent than when the metal is presented to it in the form of filings or leaves. The *nascent state* is also peculiarly favourable to chemical combination.

Tables of affinity consist of a series of substances placed in a column, in the order of their affinity for any one substance at the head of the column, as in the following example:

> *Sulphuric Acid.*
> Baryta,
> Strontia,
> Potash.
> Lime,
> Magnesia,
> Ammonia.

The Atomic Theory.—The doctrine of *atomic weights* and *chemical equivalents* is based upon the supposition that every substance is divisible into ultimate particles termed *atoms,* which atoms unite together in certain definite proportions to form various compound bodies.

The *Chemical Equivalent* of a body is the number expressing its *least combining proportional;* as these merely express the ratio, any one body may be selected as a standard; either oxygen or hydrogen are generally employed,—more frequently hydrogen,—which being placed at unity, the *equivalent number* or *chemical equivalent* of oxygen would be 8; since eight atoms of oxygen always unite with one of hydrogen. In the same way the equivalent of chlorine has been fixed at 36; that of nitrogen at 14; that of iron at 28; and so on. An atom of a compound body will of course be compound, as an atom of water, or of sulphuric acid; so also, the *chemical equivalent* of a compound body is the sum of the equivalents of its constituents; thus the equivalent of water is 9 (8+1); that of sulphuric acid 40 (16+24); and so on.

LAWS OF CHEMICAL COMBINATION.

1. All chemical compounds are fixed and definite in their nature, the ratio of the elements being constant. This is termed the *law of definite proportions*.

2. *The law of multiple proportions.*—When any body is capable of uniting with a second in several proportions, these proportions bear a simple relation to each other. This is well illustrated in the series of compounds of nitrogen and oxygen, in which, while the nitrogen remains the same, the quantities of oxygen increase by multiples of 8; thus 8, 8×2, 8×3, 8×4, 8×5 give respectively the quantities of oxygen contained in the protoxide of nitrogen, the deutoxide, hyponitrous acid, nitrous acid, and nitric acid.

3. *The law of equivalents.*—The proportions in which several bodies unite with any given body represent the relations in which they unite among themselves. Take oxygen as an example : the proportions in which sulphur, chlorine, carbon, and iron unite with oxygen, are respectively 16, 36, 6, and 27, for every 8 parts of oxygen. Now, according to the above law, these bodies will combine with each other in the same proportion,—thus carbon and oxygen in the ratio of 6 to 8, &c. These proportions are named *equivalents* or *combining* numbers. The law holds equally true for compound bodies.

It is obvious that any body may be assumed as unity ; generally hydrogen is so assumed, in which case the equivalent of oxygen is 8.

SECTION I.

SIMPLE NON-METALLIC BODIES.

OXYGEN.

EXISTS abundantly in nature, constituting one-fifth of the atmosphere, and eight parts in nine of water ; also, in all organic matter.

Discovered in 1771 by Priestley, and by Scheele in 1775; named *dephlogisticated air* by Priestley, *empyreal air* by Scheele, and *vital air* by Condorcet ;—the name *oxygen*, derived from two Greek words signifying to *generate an acid*, was given by Lavoisier, under the idea that it was the sole acidifying principle.—*Prepared* by heating either the peroxides of mercury, lead, or manganese, or the nitrate or chlorate of potassa. When either of the peroxides is exposed to heat, a portion of their oxygen is driven off, and they are converted into either protoxides or sesquioxides. Perhaps the best mode of procuring it is to heat the chlorate of potassa, which yields a large quantity of oxygen,—the gas coming both from the acid and base, and the salt becoming converted into the chloride of potassium. This is shown by the following diagram :

Chlorate of Potassa { Chloric Acid { Chlorine - - - - - - - → Chloride of Potassium. / 5 Oxygen } Potassa { Potassium / Oxygen - - - - - - → 6 eq. oxygen. }
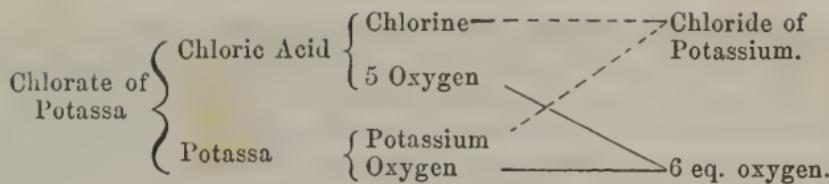
If a little powdered peroxide of manganese be previously mixed with the chlorate of potassa, a less amount of heat will be required, although none of the oxygen comes from the manganese. Oxygen should be collected over water, in a *pneumatic trough*,—a large vessel containing water, and fitted with a shelf for holding the receivers, which must always be below the level of the liquid.

Properties.—Colourless, tasteless, inodorous; sp. gr. 1·1026;—has never been condensed into a liquid; it is the most perfect negative electric; is very sparingly soluble in water; a powerful supporter of combustion and of life; has a strong attraction for most simple bodies. Its power of supporting combustion is shown by immersing in it a candle with a red-hot wick, which is instantly relighted; or by the burning of fine iron wire, or of phosphorus and sulphur, in it; the compounds which are always thus formed are termed either *acids* or *oxides*, according as they do, or do not, possess acid properties. *Ordinary combustion* is only the rapid union of a body with oxygen; and the body, when burnt, is always increased in weight; which increase is exactly equal to the amount of oxygen which has disappeared. Oxygen is equally essential to respiration: no animal can live in an atmosphere deprived of oxygen; pure oxygen is injurious to life, on account of its highly-stimulating properties, all of the functions becoming extremely excited. Eq.=8;—combining vol.=50;—Symbol, O.

Theory of combustion.—The term *combustion*, in its widest sense, signifies "a chemical combination, attended with the evolution of light and heat." In its *restricted* sense, it means "the rapid union of a combustible with oxygen." Before the discovery of oxygen gas, the phenomena of combustion were explained on the *Stahlian*, or *phlogistic theory*, that all combustibles contained a principle named *phlogiston*, to which they owed their combustibility; and that when they burned, they gave out their phlogiston, and then ceased to be combustible. A metallic oxide was consequently regarded as a simple substance, and the metal itself as a compound of the oxide with phlogiston.

Lavoisier proved the incorrectness of this doctrine, by showing that a body on undergoing combustion, so far from giving out anything, always acquires oxygen; thus, on burning a piece of phosphorus in oxygen, some of the gas disappeared, the phosphorus increased in weight, and the increase of the latter was precisely equal to the loss of the former. Lavoisier, however, went too far

in supposing that oxygen was the *sole* supporter of combustion ;
since it has been proved that other gases, as chlorine, cyanogen, &c.,
will also support it. He also accounted for the intense light and
heat produced during combustion, on the principle of latent heat ;
but in this he was subsequently proved to be incorrect. No certain
explanation of these phenomena have indeed been given, though
they have been attributed to *chemical action* by some, and to *elec-
tricity* by others ; this latter view is adopted by Berzelius.

All combustibles do not emit an equal amount of heat on being
burned.

HYDROGEN.

Exists abundantly in nature ; constitutes one-ninth by weight, of
water, and two-thirds by volume ; named from the Greek words sig-
nifying *to generate water*. *Prepared*, always by decomposing water,
which may be effected either by bringing steam in contact with red
hot iron, which then combines with the oxygen of the water, libe-
rating pure hydrogen ; or by the action of dilute sulphuric acid on
pieces of zinc or iron ; in this case the water of the sulphuric acid
yields its oxygen to the zinc, and its hydrogen escapes : the oxide of
zinc at the same time unites with the acid to form the *sulphate of
zinc,* thus :—

Water $\begin{cases} \text{Hydrogen} \\ \text{Oxygen} \end{cases}$ ————————————Free.

Zinc——————————— oxide of zinc $\begin{cases} \text{Sulphate of} \\ \text{oxide of zinc.} \end{cases}$
Sulphuric acid ————————
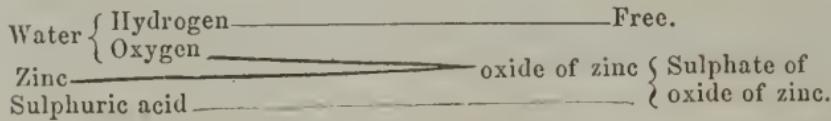
Prop.—Colourless, inodorous, tasteless ; the lightest body in na-
ture, sp. gr. 0·06896 ; 100 cubic inches only weigh 2·137 grs.   It
cannot be compressed into a liquid ; a non-supporter of combustion
and respiration, though this latter property arises, not from any
noxious property of the gas, but only from an absence of oxygen ; it
is highly inflammable, burning with a pale bluish flame ; when mixed
with a due proportion of oxygen (2 measures of hydrogen to 1 of
oxygen), it explodes violently, either by a heated body, or the elec-
tric spark, giving rise to the formation of water.

Spongy platinum is instantly made red hot by a jet of hydrogen,
which, in its turn, is then inflamed ;—a mixture of hydrogen and
oxygen, will burn slowly without explosion, when the temperature
is raised a little above that of boiling mercury.   The burning of
hydrogen with oxygen is accompanied with the evolution of a great
amount of heat ; on this principle the *oxy-hydrogen blowpipe* is
constructed, consisting of an apparatus by which a mixture of hy-
drogen and oxygen is made to burn from a jet, care being taken to
guard against the danger of explosion, by means of Hemming's
safety tube ; the heat thus produced is sufficient to melt the most

refractory metals. A burning jet of this when thrown upon a piece of lime constitutes the *Drummond light.*—Symb. H ;—Eq. 1.

Hydrogen forms two compounds with oxygen : water, or the *protoxide,* and the *peroxide.*

Water, HO.—First proved to be composed of hydrogen and oxygen, by Cavendish; this may be shown *synthetically,* by mixing one volume of oxygen with two of hydrogen, and exploding the mixture, when water will be the sole product,—or, *analytically,* by decomposing water either by a red-hot iron, or by galvanism; in the last case, a small portion of water is interposed between a pair of platinum plates connected with the extremities of a voltaic apparatus of moderate power; pure oxygen gas is evolved at the positive plate (or that connected with the copper end), and pure hydrogen at the negative, or zinc extremity; the gases may be properly collected and measured.

Fig. 17.

The composition of water is, by weight, 8 parts of oxygen, and 1 of hydrogen ; by volume, 1 volume of oxygen, and 2 of hydrogen.

Prop.—Colourless, inodorous, tasteless ; a powerful refractor of light; an imperfect conductor of heat and electricity ; very incompressible ; sp. gr. 1. It does not occur, in nature, chemically pure ; can only be procured pure by distillation. Freezing point, 32° F. ; boiling point, 212° F. ; greatest density, at 40° F. Water acts powerfully as a chemical agent, both as an acid and as a base ; in the first case, forming compounds termed *hydrates,* when sometimes the reaction is accompanied with the evolution of heat, as in the slaking of lime ; in the second case, uniting with the so-called acids ; dry sulphuric acid can evince no acid properties, unless water be present to act as its base, but this base may be substituted by a more powerful one, as the oxide of iron, or of zinc. Water also enters into the composition of many crystals, constituting their *water of crystallization.* Its *solvent* properties are pre-eminent. Water in its natural state always contains atmospheric air, as may be shown by placing it under a receiver and exhausting the air ; bubbles of gas will make their escape. Recently-boiled water has the property of absorbing gases, though in different degrees.

Peroxide of Hydrogen, HO_2, called also *oxygenated water,* is procured from the peroxide of barium, by the action of dilute hydrochloric acid, and then precipitating the baryta by sulphuric acid ; the excess of oxygen of the peroxide, instead of escaping, unites with the water, converting it into the peroxide of hydrogen.

Prop.—A colourless, transparent liquid; inodorous ; has a metallic taste ; sp. gr. 1·45 ; remarkable for its proneness to decom-

position,—a temperature of 212° causing explosion; it also bleaches and oxidizes.
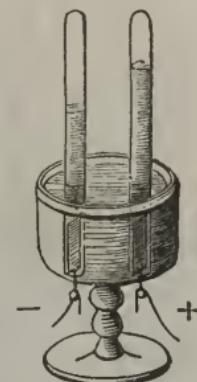
NITROGEN.

Constitutes about four-fifths of the atmosphere, and is found abundantly in nature, under various combinations. It may be procured in several ways, of which the most simple is to burn out the oxygen from a confined portion of air, in a bell-glass inverted over a dish of water, by means of a piece of phosphorus; the phosphorus is converted into phosphoric acid, and the remaining gas is tolerably pure nitrogen. A purer gas may be obtained by passing atmospheric air over copper heated to redness; or by passing chlorine through a solution of ammonia (nitrogen and hydrogen);—in this last case there is a risk of the formation of the chloride of nitrogen, a very explosive compound.

Fig. 18.

Prop.—Distinguished for its negative properties; destitute of colour, taste, and smell; a non-supporter of combustion and life; has no noxious properties; is not inflammable; sp. gr. ·972; Eq. $= 14·15$; Symb. N.

Nitrogen forms five compounds with oxygen, and one mixture, viz.: the atmosphere.

The *atmosphere* is composed of about four-fifths of nitrogen, one-fifth of oxygen, and some carbonic acid and watery vapour. The air may be analyzed either by burning a piece of phosphorus in a known portion of it, or by passing it over a finely-divided copper, heated to redness, or by mixing it with hydrogen in definite proportions, and exploding the mixture by the electric spark; the last method is best accomplished by means of a *eudiometer*—a stout glass tube, so arranged that known bulks of gas can be measured. Suppose 100 measures of atmospheric air be mixed with 50 of hydrogen, and the mixture exploded; the volume, after explosion, will be found reduced to 87 measures; hence there has been a diminution of 63 measures, of which one-third, or 21 measures, is oxygen; the remaining two-thirds is hydrogen.

Prop.—Colourless and invisible; when pure, has no taste or smell; sp. gr. 1; it is 800 times lighter than water at 60°. At the level of the sea, it exerts a pressure of 15 pounds on every square inch, and is capable of supporting a column of water 34 feet high, and one of mercury 30 inches; that is, a column of mercury one inch square and 30 inches long, has the same weight (nearly 15 pounds) as a column of water 34 feet long, and as a column of air of equal base reaching to the extreme limit of the atmosphere.

COMPOUNDS OF NITROGEN WITH OXYGEN.

These are Protoxide of Nitrogen, Deutoxide of Nitrogen, Hyponitrous Acid, Nitrous Acid, and Nitric Acid.

Protoxide of nitrogen, NO, called also *nitrous oxide*, and *laughing gas;*—prepared by heating the nitrate of ammonia. The rationale is as follows :

Nitrate of Ammonia $\left\{\begin{array}{l}\text{Nitric acid}\left\{\begin{array}{l}\text{Nitrogen}\\2\text{ Oxygen}\\3\text{ Oxygen}\end{array}\right. \\ \\ \text{Ammonia .}\left\{\begin{array}{l}\text{Nitrogen}\\3\text{ Hydrogen}\end{array}\right.\end{array}\right.$ $\longrightarrow$ 2 eq. Nitrous oxide.

$\longrightarrow$ 3 eq. Water.
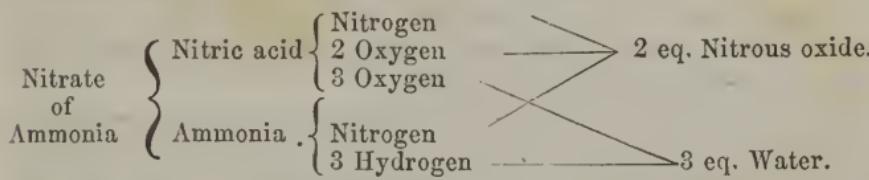
Prop.—Colourless, transparent, almost inodorous; sp. gr. 1·5; a powerful supporter of combustion; water dissolves nearly its own volume; may be condensed into a liquid at 45° by a pressure of 50 atmospheres; when mixed with hydrogen in equal volumes, it explodes with violence by the electric spark, liberating its own measure of nitrogen. Its most remarkable property is its exhilarating effect on the animal system, when respired.

Deutoxide, or *Binoxide of nitrogen*, NO_2;—prepared by the action of nitric acid on copper turnings; part of the oxygen of the acid combines with the copper, the oxide thus formed uniting with the undecomposed nitric acid; another portion of the oxygen unites with the nitrogen to form the deutoxide. It is colourless, but has a strong affinity for oxygen; it acquires a dark red colour when it comes in contact with the air, which will serve to distinguish it; it is irrespirable; a supporter of combustion in some cases,—as of charcoal and phosphorus; but it extinguishes a lighted candle. From its affinity for oxygen, it may be used with advantage in *eudiometry*.

Hyponitrous acid, NO_3; prepared by adding four measures of deutoxide of nitrogen to one of oxygen, and exposing the mixture to a temperature of 0° F.; they condense into a thin liquid of a greenish colour;—vapour, orange red; it is decomposed by water into nitric acid and deutoxide of nitrogen; it cannot be made to unite *directly* with metallic oxides.

Nitrous acid, NO_4, is always formed whenever deutoxide of nitrogen comes in contact with the atmospheric air, producing dense orange-coloured fumes;—procured in a liquid form by heating nitrate of lead in a retort; oxide of lead remains behind, and the acid is resolved into a mixture of oxygen and nitrous acid, the latter being condensed into a liquid by surrounding the receiver by a powerful freezing mixture.

Prop.—At a low temperature it is nearly colourless; acquires an orange tint on raising the temperature; sp. gr. 1·451; very volatile, boiling at 82°;—is acid, pungent, and corrosive; is decomposed, on

being added to water, into nitric acid and deutoxide of nitrogen;
very irrespirable; supports the combustion of a burning taper and
of phosphorus, but extinguishes sulphur;—a powerful oxidizing
agent.

Nitrous acid combines with nitric acid, which thereby acquires a
strong orange tint, and constitutes the fuming-red *nitrous acid* of
the shops, and the *nitroso-nitric acid* of Berzelius. The colour of
the mixture varies with the strength of the nitric acid, becoming
yellow, green, and blue, and finally disappearing altogether, as the
quantity of water in the acid increases.

Nitric acid, NO_5;—procured synthetically, by passing a succession
of electric sparks through a mixture of nitrogen and oxygen confined
in a tube;—best prepared by the action of sulphuric acid on nitre
(nitrate of potassa) with the aid of heat; nitric acid vapours pass
over along with water, and the bisulphate of potassa remains in the
retort: this constitutes the *aqua fortis* of commerce.

Prop.—When thus procured, liquid nitric acid is of a yellowish
colour, which is dependent upon some nitrous acid fumes; when
perfectly pure it is colourless; sp. gr. about 1.5; contains about 25
per cent. of water, without which it cannot exist as an *acid*, though
it has lately been isolated in a dry crystalline form; emits dense,
white, suffocating fumes when exposed to the air; boils at 187°.
On adding different portions of water to the strong acid, several
definite combinations of acid and water appear to be generated, re-
markable for the difference observed in their boiling and freezing
points.

The nitric acid of commerce is apt to contain traces of sulphuric
and hydrochloric acids; the former is detected by adding chloride
of barium—an insoluble sulphate of baryta being precipitated; the
latter, by nitrate of silver—an insoluble chloride of silver being
thrown down. Nitric acid is a powerful oxidizer, acting with great
violence on many of the metals; it decomposes all organic sub-
stances, and acts on the skin as a caustic. The salts formed by
nitric acid are termed *nitrates*.

The best tests for nitric acid are,—its solvent power over gold, if
hydrochloric acid be present; the formation of the well-known
nitrate of potassa; the red tint communicated to a salt of morphia;
and the bleaching effect upon a boiling solution of sulphate of in-
digo, provided no chlorine be present.

CARBON.

This is a very abundant product of nature, being a constituent of
all organic bodies; its purest form is the diamond, a native crystal
of carbon; which is proved to be pure carbon by burning it in oxy-
gen gas, the sole product being carbonic acid. The next purest
native variety is graphite or plumbago, which also contains some

iron; next to this comes anthracite coal. It is the essential ingredient of common charcoal, which is prepared by burning wood in close vessels. *Coke* is the charcoal of bituminous coal; *lamp-black*, that of resin; *ivory-black* or animal charcoal is prepared from bones.

Prop.—Carbon, as it exists in the diamond, is the hardest substance in nature; it crystallizes in the form of the octohedron or cube; sp. gr. 3·52; is very unchangeable; bears an intense heat in close vessels without fusing; is not acted on either by acids or alkalies. As obtained from wood, it is hard and brittle; its apparent lightness is due to its porosity. It is a bad conductor of heat; a good conductor of electricity; and is very combustible, when burnt in the air or in oxygen, giving rise to carbonic acid; has the property of absorbing a large quantity of gases or vapours into its pores, though in very different proportions; thus, of ammonia, 90 times its volume is absorbed, while of hydrogen, it takes up less than twice its own bulk.

Another very useful property of charcoal is its power of absorbing the colouring matters from organic solutions; animal charcoal is best for this purpose. Charcoal is also highly antiseptic; it is hence used for purifying water, in filtering machines; also to remove the odour from tainted flesh.—Eq.$=6·12$.—Symb.$=C$. It forms two direct compounds with oxygen, namely, carbonic oxide, and carbonic acid.

Carbonic oxide gas, CO.—Prepared by passing carbonic acid gas over red-hot charcoal or iron, one half of its oxygen being removed and it becoming converted into carbonic oxide; or preferably by the action of sulphuric acid or oxalic acid (an organic acid consisting of equal measures of carbonic acid and carbonic oxide), which is immediately resolved into its constituents; and on passing the gases through a strong solution of potassa, the carbonic acid is absorbed, and the carbonic oxide may be collected.

Prop.—Colourless and inodorous; sp. gr. 0·9927; sparingly absorbed by water; is neither acid nor alkaline; a non-supporter of combustion, but combustible, burning with a lambent blue flame, giving rise to carbonic acid; it is irrespirable. Mixed with oxygen it may be exploded by the electric spark, forming carbonic acid.

Carbonic acid, CO_2.—Discovered by Dr. Black in 1757, and named by him *fixed air;* prepared by the action of sulphuric or muriatic acid on any carbonate; the gas comes off with effervescence.

Prop.—Colourless; of a pungent odour and taste; very irrespirable; sp. gr. 1·524. It may be condensed into a liquid at 32° by a pressure of 36 atmospheres; this liquid may be frozen by the cold produced by its own evaporation, which is estimated at 148°. The liquefied acid is colourless, and limpid like water; the *solid* acid resembles snow. Carbonic acid acts upon animals as a poison pro-

ducing asphyxia; it is injurious even when largely diluted with air; hence the evils resulting from imperfect ventilation. It sometimes accumulates in wells and mines, constituting the *choke-damp* of miners. Water absorbs its own volume of this gas, at any pressure; consequently the amount absorbed is determined simply by the degree of pressure to which the gas is subjected; in this way carbonic acid water is manufactured. Carbonic acid exists in the air, as has been mentioned; also in common spring water, which owes to it its pleasant flavour; the gas may be entirely driven off by boiling; hence water which has been boiled is quite insipid. Its solution in water forms one of the great solvents of nature; by means of it, rocks are disintegrated and converted into soils. Its salts are numerous; they are named *carbonates*, the most common of which is *limestone*.

The best test for carbonic acid is *lime-water*, to which it always imparts a cloudiness, resulting from the formation of carbonate of lime. This may be seen also by breathing through a tube immersed in lime-water.

SULPHUR.

Is found uncombined in the neighbourhood of volcanoes, as in Italy and Sicily; also abundantly in a state of combination with various metals, as iron, lead, copper, antimony, &c., constituting the *pyrites* of mineralogists. It is procured by exposing iron pyrites to a red heat, in close vessels.

Prop.—A yellow brittle solid, without odour and taste, under ordinary circumstances, but acquires a peculiar odour when rubbed; sp. gr. 1·99; a non-conductor of heat and electricity; melts at 232°, at which point it is a liquid of an amber colour. If the heat be increased it begins to thicken and acquires a reddish tint; between 428° and 482°, it is thickest; and beyond this it again becomes thinner up to its boiling point, 600°; burns when heated up to 300° in the open air. The *roll brimstone* of commerce, is melted sulphur run into cylindrical moulds. *Flowers of sulphur* are minute crystals of sulphur, obtained by subliming sulphur in close vessels. The sp. gr. of the vapour is 6·654. The vapour will support combustion. Crystals of sulphur may be procured by melting any quantity in an earthen vessel, and when partially cooled, breaking the crust and pouring out the liquid contents. Crystals are often found on breaking the roll brimstone of commerce.

Sulphur is insoluble in water; soluble in the fixed and volatile oils; the best solvent is the bisulphuret of carbon; it dissolves in alcohol if both substances are brought together in the state of vapour. Eq.=16. Symb. S.

It much resembles oxygen in its chemical habitudes, like that body generating both acids and bases.

Sulphur forms six compounds with oxygen, of which the most important are sulphurous and sulphuric acids.

Sulphurous acid, SO_2—the product when sulphur is burned in the open air, or in dry oxygen;—prepared conveniently by the action of sulphuric acid on mercury or copper; a part of the acid is decomposed, yielding up sulphurous acid and oxygen; the oxygen uniting with the metal.

Prop.—Colourless; of a pungent, suffocating odour, and acid taste; sp. gr. 2·2105;—is condensed into a liquid at 45° by a pressure of two atmospheres, and at 0° under a pressure of one atmosphere;—a non-supporter of combustion, and a non-combustible;—cannot support respiration; water at 60° absorbs 32 times its volume. It possesses bleaching properties; its solution first reddening and then bleaching litmus. Its salts are termed *sulphites*: they are not of much importance.

Sulphuric acid, SO_3—Known in commerce as *oil of vitriol*;—may be procured in two modes: first, by exposing the protosulphate of iron (green vitriol) to a red heat, by which the sulphuric acid is driven off, and condensed, and the peroxide of iron remains. The acid thus procured is an oily brown liquid, of a sp. gr. of 1·9, fuming in the air, and very corrosive; it is known in commerce as *fuming sulphuric acid*, or *acid of Nordhausen*, from the place of its manufacture.

The second method is the one usually adopted. It depends upon the fact that when sulphurous and nitrous acid are present along with some water, the sulphurous acid takes oxygen from the nitrous acid, the first becoming sulphuric acid, and the last deutoxide of nitrogen. The mode adopted is the following: A mixture of sulphur and nitre is exposed to heat in such a manner, that the vapours are carried into a leaden chamber, upon the bottom of which is a stratum of water. The nitric acid of the nitre gives up oxygen to some of the sulphurous acid, thereby converting it into sulphuric acid, which immediately combines with the potassa; the greater part of the sulphurous acid enters the leaden chamber, when it comes in contact with deutoxide of nitrogen, atmospheric oxygen, and watery vapours, forming a white crystalline compound, believed to be composed of sulphuric acid, hyponitrous acid, and water. When this solid falls into the water on the floor of the leaden chamber, it is decomposed into sulphuric acid (which is dissolved by the water), nitrous acid and deutoxide of nitrogen. The nitrous acid thus set free, as well as that produced by the reaction of atmospheric oxygen on the deutoxide of nitrogen, is again mingled with sulphurous acid and watery vapours as before, and gives rise to the formation of another portion of the crystalline compound, which, in its turn, becomes decomposed on falling into the water. When the water in the leaden chamber

becomes sufficiently saturated, it is drawn off and concentrated in platinum vessels, by heat, until it attains the sp. gr. of about 1·84.

The theory of the process may be expressed thus :—

Nitrous acid. $\begin{cases} \text{Nitrogen} \\ \text{2 Oxygen} \end{cases}$ ——— Deutoxide of Nitrogen.

2 Sulphurous acid. $\begin{cases} \text{2 Oxygen} \\ \text{2 Sulphur} \\ \text{4 Oxygen} \end{cases}$

Water ——————————→ 2 Hydrated Sulphuric acid.
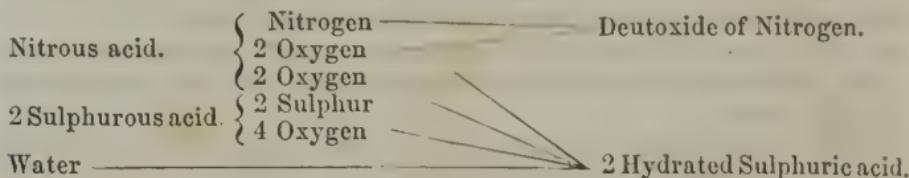
Prop.—A dense, colourless, oily liquid, of an intensely sour taste and acid reaction ;—consists of 40 parts, or 1 eq. anhydrous acid, and 9 parts or 1 eq. water ;—extremely corrosive ;—decomposes all organic substances ;—has a powerful attraction for water, and when mixed with it gives rise to a great elevation in the temperature; freezes at —15° and boils at 620°.

Anhydrous sulphuric acid may be procured by heating the Nordhausen acid in a retort, to which is adapted a receiver surrounded with ice; a vapour passes over, which condenses into white silky crystals, resembling asbestos. It has such a strong affinity for water, that when put into that liquid it hisses like a hot iron ; it is very volatile, boiling at 104° ;—it does not display any acid reaction unless moisture be present. *Test,* chloride of barium.

Hyposulphurous acid, S_2O_2, cannot exist in an isolated form; it is produced when sulphur is digested in a solution of sulphate of potassa ;—a *hyposulphite* of potassa is formed.

Hyposulphuric acid, S_2O_5, is procured in solution by suspending peroxide of manganese in water artificially cooled, and then transmitting through it a stream of sulphurous acid gas ; the *hyposulphate* of the protoxide of manganese is thus formed, which is decomposed by baryta, and the barytic salt in its turn decomposed by sulphuric acid.

Two other acids of sulphur have recently been discovered, called respectively the *sulphuretted hyposulphuric acid,* S_3O_5, and *bisulphuretted hyposulphuric acid,* S_4O_5.

SELENIUM.

A very rare substance, much resembling sulphur in its chemical habitudes. It is a reddish brown solid body, having an imperfect metallic lustre, and a sp. gr. of 4·3 ;—melts at about 212° and boils at 650°. It forms an oxide and two acids.

PHOSPHORUS.

Exists in bones and urine ;—prepared from bones, in which it exists as phosphate of lime, by calcining, and then adding sulphuric acid and water; the sulphate of lime is precipitated, and the phos-

phorie acid left in solution with some of the lime, as a superphosphate. This is evaporated, mixed with charcoal and exposed to a high heat; the phosphorus distils over into water.

Prop.—When pure it much resembles wax, being soft and flexible, and of a flesh colour; sp. gr. 1·77;—fuses at 108°;—boils at 550°; —insoluble in water, but dissolves in naphtha and oils;—very inflammable;—burns with a bright flame generating phosphoric acid. It undergoes a slow combustion in the open air, giving a luminous appearance in the dark; this combustion may, however, be entirely prevented by the presence of olefiant gas, vapour of ether, or an essential oil. Eq.=15·7, or (according to some) 31·4. Symb. P.

Phosphorus forms four compounds with oxygen.

Oxide of phosphorus, P_3O, or P_2O, formed by melting phosphorus under hot water, and bringing a stream of oxygen gas in contact with it:—it has a red colour;—is insoluble in water, alcohol, or ether.

Hypophosphorous acid, P_2O, or PO;—is formed when phosphuret of barium is put into water; it is a powerful deoxidizing agent.

Phosphorous acid, P_2O_3, or PO_3; formed by burning phosphorus in a limited supply of oxygen or air; in this state it is anhydrous, and is in the form of a white powder, very deliquescent. It forms *phosphites*, which are of little importance.

Phosphoric acid, P_2O_5, or PO_5;—prepared by burning phosphorus in the open air or in oxygen, by which it is procured in the anhydrous form; also by heating phosphorus in nitric acid; also from bones, by acting on the phosphate of lime (which is formed as already described) by carbonate of ammonia, then evaporating the phosphate of ammonia, and heating in a platina crucible.

Prop.—Very deliquescent; is a powerful acid; very sour, but does not corrode like nitric and sulphuric acids. It is capable of existing in three different states or modifications, forming three separate classes of salts, which differ completely in properties and constitution. They are distinguished by the names *tribasic, bibasic,* and *monobasic* acids, according to the number of equivalents of base required to form neutral salts.

The *tribasic phosphoric acid* is the acid of the well-known phosphates; it is characterized by yielding with a soluble salt of silver, a yellow insoluble phosphate. It contains 3 eq. water.

The *bibasic phosphoric acid*, also called the *pyrophosphoric acid*, is procured by heating the former acid at a temperature of 415°;— it is distinguished from the tribasic acid by yielding a *white* instead of a yellow precipitate with the salts of silver. It contains 2 eq. of water.

The *monobasic phosphoric acid*, also named *paraphosphoric acid*, is procured when phosphorus is heated in the open air, and also when a concentrated solution of the tribasic or bibasic acids is heated

to redness. By the former method, it is anhydrous; by the latter it is a hydrate. The hydrate is very fusible, and on cooling it condenses into a transparent brittle solid, called *glacial phosphoric acid*, which is very deliquescent. It contains 1 eq. of basic water. It forms an insoluble compound with albumen.

BORON.

Is the basis of boracic acid;—may be procured from boracic acid by heating it with potassium; the oxygen of the acid, uniting with the potassium, sets the boron free.

Prop.—A dark olive-coloured substance; insoluble; a non-conductor of electricity; when burned in the open air or oxygen, it generates boracic acid. Eq.=10. Symb. B. It forms only one compound with oxygen, namely, *boracic* or *boric acid*. This can be procured by decomposing biborate of soda (borax) by means of sulphuric acid; the sulphate of soda remains in solution, and the boracic acid is deposited in the form of crystals.

It is sparingly soluble in cold water, more so in hot water, and very soluble in boiling alcohol. The alcoholic solution when set on fire, burns with a beautiful green flame,—a good test of its presence. When boracic acid is heated, it melts into a glassy mass.

The most important salt of boracic acid is *borax*—a biborate of soda.

SILICON.

The basis of silex or silicic acid;—procured by heating the double fluoride of silicon and potassium; the latter combines with the fluorine, liberating the silicon.

Prop.—A dark brown powder, a non-conductor of electricity, and without the metallic lustre; heated in the air, it burns and is converted into silicic acid;—forms only one compound with oxygen. Eq.=22·18. Symb. Si.

Silicic acid, SiO_3,—known also as silex or siliceous earth—exists abundantly in nature in the form of quartz and sand. Rock crystal is a very pure form of it.—Prepared by igniting transparent rock crystal, throwing it when red hot into water, and then reducing to powder; or by heating together powdered quartz or sand, and carbonate of soda: a silicate of soda is formed, which is to be boiled in water; hydrochloric acid is then added, which combines with the soda, precipitating the silicic acid in the form of a gelatinous mass.

Prop.—A white powder, insoluble, tasteless; sp. gr. 2·69; very infusible; has no action on test paper on account of its insolubility; but it is a powerful acid, since it forms salts with the alkalies. Common glass is a silicate of potash. The best varieties of glass are made out of pure alkali and very fine sand, free from iron: flint-glass contains also some litharge or red lead. If the proportion be re-

versed, so as to have one part of silicic acid with three of potash, we have a soluble silicate of potash, called *liquor silicum*, or *liquor of flints*.

CHLORINE.

Chlorine, along with Iodine, Bromine, and Fluorine, forms a group of simple bodies whose chemical habitudes are remarkably similar. They, together with Cyanogen (a compound body), are termed *halogen bodies*, because they form salts resembling sea-salt, or chloride of sodium.

Chlorine exists abundantly in nature as an ingredient in common salt. It was discovered, in 1774, by Scheele, and by him called *dephlogisticated marine acid*. The French chemists named it *oxymuriatic acid*, from an opinion that it consisted of muriatic acid and oxygen. In 1809, Davy discovered its true nature, and gave to it the name of *chlorine*, from a Greek word signifying greenish-yellow. Prepared by the action of hydrochloric acid on peroxide of manganese, with the aid of heat; chlorine is set free, and water and a chloride of manganese are formed, thus:
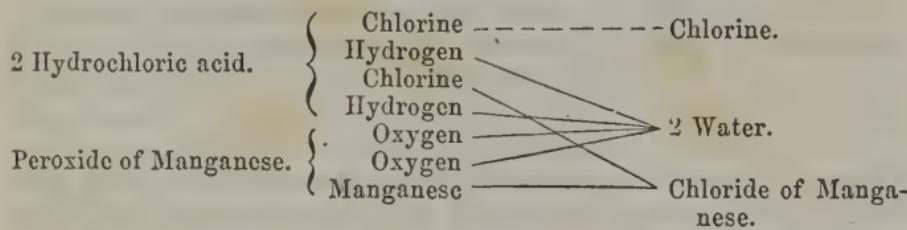
Prop.—A yellowish-green gas, irrespirable, exciting strong spasms of the glottis;—sp. gr. 2·47; water at 60° absorbs twice its volume. It is best collected by conducting it, by means of a tube, into the bottom of tall receivers, the air being thereby displaced. The watery solution, on being exposed to the light, is slowly changed into chloro-hydric acid, oxygen being set free. When moist chlorine is exposed to a cold of 32°, yellow crystals are formed, being a compound of chlorine and water. Chlorine is condensed into a liquid by a pressure of four atmospheres. It is a non-combustible, but a supporter of combustion; a lighted taper burns in it for a short time, but several of the metals, as antimony, tin, copper, and arsenic, take fire spontaneously when presented to it in a finely-divided state. In these cases, a *chloride* of the metal is formed. The strongest affinity of chlorine is for hydrogen: it is in consequence of this that it acts so powerfully as a *bleaching* agent, water being always decomposed in the process, the hydrogen uniting with the chlorine to form chlorohydric acid, and the oxygen which is set free being the real decolorizing agent.

Chlorine is also useful as a *disinfecting* agent. The best test for

chlorine is a soluble salt of silver ;—a white insoluble chloride of silver is formed.

The non-acid compounds of chlorine are called *chlorides.* Eq.=36. Symb., Cl.

Chlorine forms *four* compounds with oxygen ; none of them are very permanent, but they are all easily decomposed.

Hypochlorous acid, ClO, or protoxide of chlorine, is obtained by the action of chlorine gas on peroxide of mercury, thus :—

2 Chlorine $\begin{cases} \text{Chlorine} \\ \text{Chlorine} \end{cases}$ ⟶ Chloride of Mercury.

Oxide of $\begin{cases} \text{Mercury} \\ \text{Oxygen} \end{cases}$ Hypochlorous acid.
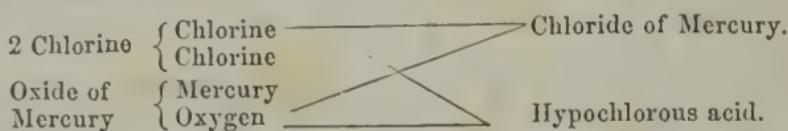
It is a pale yellowish gas,—possesses powerful bleaching properties, and forms bleaching salts.

Chlorous acid, ClO_4, peroxide of chlorine ;—prepared by heating a mixture of sulphuric acid and chlorate of potassa ; the chloric acid which is set free is spontaneously decomposed into chlorous acid and hypochloric acid, the latter remaining in union with the potassa. It has a richer colour than chlorine, and is very explosive.

Chloric acid, ClO_5, the most important compound of the series ; —prepared by adding sulphuric acid to the chlorate of baryta. If chlorine gas be transmitted through a solution of caustic potassa, a chlorate of potassa crystallizes, and the chloride of potassium remains in solution. The chlorates are easily recognised ;—they give out pure oxygen when heated, passing into chlorides ; they yield chlorous acid on being heated with sulphuric acid ; but give no precipitate with silver.

Perchloric acid, ClO_7, prepared by acting on the perchlorate of potassa with sulphuric acid. It has a very strong affinity for moisture ;—forms salts resembling the chlorates.

Chloride of nitrogen, ClN_4, prepared by transmitting chlorine gas through a solution of muriate of ammonia ; globules of an oily aspect are formed, which subside to the bottom ;—it is the most explosive substance known.

Chlorine also forms compounds with carbon, carbonic acid, phosphorus, boron, and silicon. The important compound of chlorine and hydrogen will be described subsequently.

IODINE.

Exists in sea-weeds, and in certain saline springs ;—usually prepared from *kelp*, an impure carbonate of soda ; the mother waters of this contain iodine in combination with sodium, or potassium. From this the iodine may be evolved by the action of sulphuric acid and peroxide of manganese ; the rationale is as follows :—

Iodide of	{ Iodine	- - - - - - - - - - - - - - - - - - -Iodine.
Sodium	{ Sodium	
2 Sulphuric	{ Sulphuric acid	→Sulphate of Soda.
acid	{ Sulphuric acid	
Peroxide of	{ Oxygen	{ Sulphate of Manga-
Manganese	{ Protoxide of Manganese.	{ nese.

Prop.—A solid of a bluish-black colour, and metallic lustre; in crystalline scales;—sp. gr. 49; fuses at 225°; boils at 347°; colour of vapour a rich violet; slowly volatile at common temperatures, exhaling an odour resembling that of chlorine; density of vapour 8·716, being the heaviest of all vapours; very sparingly soluble in water, but soluble in alcohol. The best *test* for iodine is starch, with which it forms a blue compound.

The affinities of iodine are not so strong as those of chlorine, since the latter always displaces iodine from its compounds.

The non-acid compounds of iodine are called *iodides.*—Eq.=126. Symb. I.

Iodine forms at least two compounds with oxygen.

Iodic acid, IO_5, forms iodates.

Periodic acid, IO_7.

Iodine forms a compound with chlorine, the *chloride of iodine;*— also with nitrogen, a very explosive compound, similar to the chloride of nitrogen;—also with phosphorus and sulphur.

BROMINE.

Is found in sea-water as a bromide of magnesium; also in certain saline springs;—procured from bromide of potassium by sulphuric acid and peroxide of manganese: the reaction is precisely similar to that in the case of iodine.

Prop.—A very volatile liquid, of a deep reddish-brown colour; freezes a little below 0°; boils at 116°; odour very suffocating and offensive; slightly soluble in water; more so in alcohol and ether. The aqueous solution bleaches. It is very poisonous; its chemical habitudes are closely allied to those of chlorine and iodine; it forms compounds with oxygen, chlorine, iodine, hydrogen, sulphur, phosphorus, carbon, and silicon.—Eq.=78·4. Symb. Br.

FLUORINE.

Occurs in nature in combination with calcium, in the well-known *fluor spar;* has only lately been isolated, on account of its energetic affinities. It is a yellowish gas, with an odour resembling chlorine; —has a powerful affinity for hydrogen and the metals;—sp. gr. 1·289;—Eq.=18·68. Symb. Fl. Its compounds with hydrogen, silicon, and boron will be described in the subsequent section.

SECTION II.

COMPOUNDS OF SOME OF THE FOREGOING SIMPLE SUBSTANCES WITH EACH OTHER.

COMPOUNDS OF HYDROGEN.

Chlorine and Hydrogen;—Hydrochloric acid, Chlorohydric acid, or *Muriatic acid,* HCl;—prepared by the action of dilute sulphuric acid on chloride of sodium, according to the following rationale :

Chloride of Sodium $\begin{cases} \text{Chlorine} \\ \text{Sodium} \end{cases}$ Hydrochloric acid gas.

Sulphuric acid

Water $\begin{cases} \text{Hydrogen} \\ \text{Oxygen} \end{cases}$ Sulphate of Soda.

Prop.—A colourless gas ; gives off dense fumes on exposure to the air ; has a very powerful affinity for water, and hence must be collected over mercury ; condensed into a liquid by a pressure of 40 atmospheres ; sp. gr. 1·269 ; water absorbs 418 times its bulk.

The solution of this gas in water constitutes the *muriatic acid* of commerce. This, when pure, is colourless ; but usually has a light straw colour—due to impurities, as iron, nitric and sulphuric acids, &c. When mixed with nitric acid it forms *aqua regia,* which has the property of dissolving gold, in consequence of the chlorine evolved ; water and nitrous acid are also formed at the same time. Water is essential to develope the acid properties of this acid. Strictly speaking, it is a *chloride of hydrogen;* and when added to a metal, its hydrogen is simply displaced by the latter.

Hydrogen and Iodine.—Hydriodic acid, III.—A gas much resembling hydrochloric acid ;—prepared by heating water in union with iodide of phosphorus ; the hydrogen combines with the iodine, to form hydriodic acid, and the oxygen with the phosphorus, to form phosphoric acid.

Prop.—Colourless ; acid ; has a strong affinity for moisture, and gives out white fumes in the air. It is decomposed by chlorine, with the formation of hydrochloric acid, and evolution of iodine ; sulphuric and nitric acid also decompose it by imparting oxygen, likewise evolving iodine.

Hydrogen and Bromine.—Hydrobromic acid, HBr ;—prepared like hydriodic acid, from a bromide of phosphorus.

Prop.—A colourless gas, irrespirable, acid ; is decomposed by chlorine, but not by iodine.

Hydrogen and Fluorine.—Hydrofluoric acid, HFl ;—prepared by the action of dilute sulphuric acid on fluoride of calcium (fluor

spar); the chemical changes are analogous to those occurring in the preparation of hydrochloric acid.

Prop.—At 32° it is a colourless liquid, but when exposed to the air, it flies off in dense white fumes; sp. gr. 1·0609;—its affinity for water surpasses even that of sulphuric acid, the combination being accompanied with a hissing noise; its vapour is extremely pungent; it is very destructive to organized bodies, as the skin, upon which it produces a deep and painful ulcer. It acts powerfully on glass, forming with it fluosilicic acid; on this account it must be prepared in metallic vessels. From its affinity for glass, it may be used for etching on that substance; the glass being coated with a thin film of wax and the figures traced with a pointed instrument; it is then submitted to the action of the gas, which, acting only on the exposed portions of the glass, leaves an indelible mark upon them.

Under this head it will be convenient to allude to some other compounds of fluorine.

Fluosilicic acid, or *Fluoride of Silicon*, SiFl,—is formed whenever hydrofluoric acid comes in contact with glass; it is best made by heating a mixture of powdered fluor spar and glass with strong sulphuric acid; the changes are as follows :—the hydrofluoric acid (generated by the action of the sulphuric acid on fluoride of calcium) reacts with the silicic acid of the glass so as to form water and fluosilicic acid, thus :

$$
\begin{array}{ll}
\text{Hydrofluoric acid} \left\{ \begin{array}{l} \text{Fluorine} \\ \text{Hydrogen} \end{array} \right. & \text{Fluosilicic acid.} \\
\text{Silicic acid} \left\{ \begin{array}{l} \text{Silicon} \\ \text{Oxygen} \end{array} \right. & \text{Water.}
\end{array}
$$
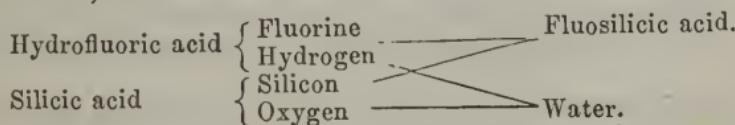
Prop.—A colourless, irritating gas, producing white fumes on escape into the air, from the action of moisture; is decomposed by water into pure silicic acid, which is deposited in flakes, and into a new acid termed *hydrofluosilicic* acid—a compound of hydrofluoric and fluosilicic acids.

Fluoboric acid, BFl₃.—Prepared by heating a mixture of powdered fluoride of calcium and vitrified boracic acid together; fluoboric acid and lime are generated.

Prop.—A colourless, pungent gas; decomposed by water into boracic acid and *borohydrofluoric* acid.

Hydrogen and Nitrogen.—*Ammonia*, or *volatile alkali*, NH₃. Prepared by heating a mixture of powdered sal ammoniac and quick lime; by a double decomposition we have gaseous ammonia, chloride of calcium, and water, thus :

$$
\begin{array}{ll}
\text{Sal ammoniac} \left\{ \begin{array}{l} \text{Ammonia} \\ \text{Hydrochloric} \left\{ \begin{array}{l} \text{Chlorine} \\ \text{acid} \quad \text{Hydrogen} \end{array} \right. \end{array} \right. & \begin{array}{l} \text{Ammonia.} \\ \text{Chloride of Cal-} \\ \text{cium.} \end{array} \\
\text{Lime} \quad . \quad . \quad . \left\{ \begin{array}{l} \text{Calcium} \\ \text{Oxygen} \end{array} \right. & \text{Water.}
\end{array}
$$
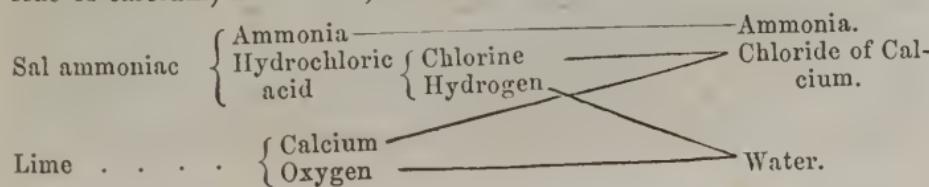
Prop.—A colourless gas, of a strong and pungent odour; very rapidly absorbed by water (more than 700 times its own volume); sp. gr. ·589; has a powerful alkaline reaction; is condensed into a liquid under a pressure of 6·5 atmospheres at 60°; cannot be formed artificially by a direct union of its elements, but is an abundant product of the putrefaction of animal substances; it may be decomposed by the electric spark, by chlorine, and by being passed through a red-hot porcelain tube.

The solution of ammonia (*aqua ammonia*) may be prepared by simply saturating water with gaseous ammonia; it is colourless, and possesses the pungent odour and alkaline reaction of the gas.

Ammonia forms salts with the different acids, which are all decomposed by a red heat, and by a less powerful heat, if they are mixed with an alkali or alkaline earth. The ammoniacal salts were formerly considered to be formed by a direct union of the alkali and the acid; but, at present, the acid is believed to unite with the oxide of a hypothetical metal termed *ammonium*. This supposed metal has never been isolated, but is inferred to exist from the fact that when ammonia is decomposed by a galvanic current, and the negative wire terminates in some mercury, an amalgam is formed, having all the characters of an ordinary metallic amalgam; but when left to itself, this amalgam rapidly decomposes into mercury, hydrogen, and nitrogen. Ammonium is believed to be composed of ammonia and one eq. of hydrogen; it is represented by NH_4, and the base of the ammoniacal salts would consequently be represented by NH_4O.

The most important of these salts are the *chloride of ammonium*, (sal ammoniac), the *carbonates*, the *nitrate*, and the *sulphate*.

There is believed to be yet another compound of hydrogen and nitrogen, to which the name of *amide*, or *amidogen*, is given. Like ammonium, it has never been isolated: it is represented by NH_2.

Hydrogen and Sulphur.—*Sulphuretted hydrogen, Hydrosulphuric acid*, HS.—Conveniently prepared by the action of dilute sulphuric acid on sulphuret of iron; or by chlorohydric acid on sulphate of antimony, as follows:—
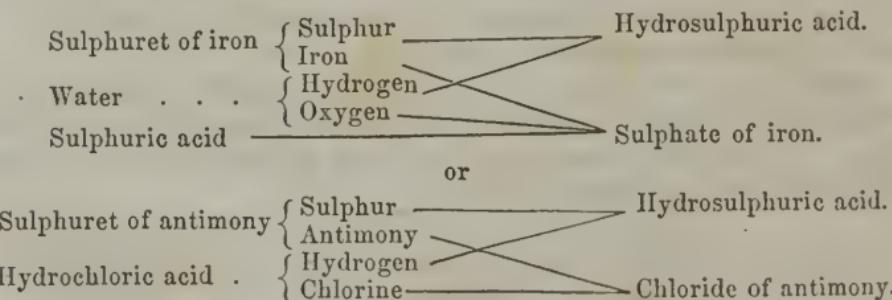
Prop.—A colourless gas, having the odour of rotten eggs; irre-

spirable, acting as a narcotic; combustible, burning with a blue flame, producing water and sulphurous acid; a non-supporter of combustion; becomes a liquid under a pressure of 17 atmospheres; is decomposed by chlorine, with a deposition of sulphur; sp. gr. 1·171; it has the properties of a weak acid, reddening litmus paper, and forming salts.

The best *test* is acetate of lead, with which it forms the black sulphuret of lead.

Hydrosulphuric acid is valuable to the chemist as a test for metallic solutions, causing with them an insoluble precipitate of the sulphuret of the metal.

There is another compound of sulphur and hydrogen, called *persulphuret of hydrogen.*

Hydrogen and Selenium.—Hydroselenic acid, HSe;—in its general properties it resembles hydrosulphuric acid.

Hydrogen and Phosphorus.—Phosphuretted hydrogen, PH_3, prepared by boiling together hydrate of lime, water, and phosphorus; the water is decomposed, and hypophosphite of lime and phosphuretted hydrogen are formed, thus:—

Water $\left\{\begin{array}{l}\text{Hydrogen}\\ \text{Oxygen—}\end{array}\right.$ $\left\{\begin{array}{l}\text{Phosphuretted}\\ \text{Hydrogen}\end{array}\right.$

2 Phosphorus $\left\{\begin{array}{l}\text{Hypophospho-}\\ \text{rous acid.}\end{array}\right\}$

Lime— $\left\{\begin{array}{l}\text{Hypophos-}\\ \text{phite of lime.}\end{array}\right.$
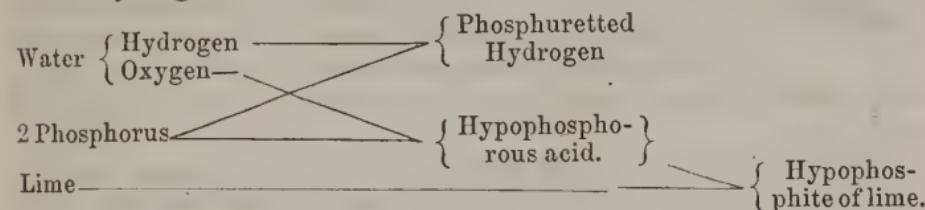
The most remarkable feature of this gas is its spontaneous inflammability; so that if the beak of the retort in which it is evolved be placed under water, as each bubble of gas rises through the liquid it takes fire, and forms a beautiful ring of a dense white smoke, which enlarges as it ascends.

COMPOUNDS OF CARBON AND HYDROGEN.

The number of these compounds has now become very great; but most of them belong properly to the domain of organic chemistry; two of them, however, are generally considered under the head of inorganic chemistry : these are Light carburetted hydrogen and Olefiant gas.

Light carburetted hydrogen, marsh gas, fire-damp, dicarburet of hydrogen, CH_2;—is formed in stagnant pools by the decomposition of vegetable matters; and may be procured by stirring up the mud at the bottom of the pool, and collecting the gas. It may be prepared by strongly heating a mixture of acetate of soda, hydrate of

Fig. 19.

potash and quicklime : the gas is derived from the decomposition of the acetic acid and water.

Prop.—Colourless, tasteless, nearly inodorous; a non-supporter of combustion or respiration, but very combustible, burning with a bright yellow flame;—mixed with oxygen in due proportions, it forms an explosive mixture; products of its explosion or combustion, water and carbonic acid; sp. gr. ·559. This gas is frequently evolved in large quantities from coal mines, and explodes on contact with the flame of the miner's lamp, causing the most disastrous consequences. Sir H. Davy's *safety-lamp* was invented to obviate these fatal results. It consists of a common oil-lamp, enclosed in a cage of wire-gauze, made double at the upper part, containing about 400 apertures to the square inch. When this lamp is taken into an explosive mixture, although the fire-damp, passing inside the gauze, may burn within the cage with such energy as to heat the metallic tissue to redness, the flame is not communicated to the mixture on the outside, in consequence of the cooling effect produced upon the heated gas by the wire-gauze; most fortunately, the fire-damp has a very high kindling point; it will not inflame at the red heat of wire gauze.

Chlorine does not act on light carburetted hydrogen, if kept in the dark; but if the light be admitted, a combination ensues, attended with the formation of hydrochloric and carbonic acids.

Olefiant gas, C_2H_2;—so called from its property of forming an oil-like liquid with chlorine. Prepared by heating a mixture of strong sulphuric acid and alcohol; at first ether is formed, and comes over along with vapour of alcohol; afterwards the olefiant gas comes over along with sulphurous and carbonic acid; the two latter are to be absorbed by potassa.

Prop.—Colourless, tasteless and inodorous; water absorbs about one eighth of its volume; a non-supporter of combustion and respiration; but burns with a dense bright light, producing carbonic acid and water; mixed with a due proportion of oxygen, it explodes by means of the electric spark; sp. gr. ·981; mixed with chlorine, it combines with it in equal measures, forming a heavy, oily liquid, of sweetish taste and ethereal odour, termed *Dutch liquid*.

Flame is gas heated to a white heat. It owes its *light* to the presence of solid particles of carbon, there not being sufficient oxygen to consume them. Hydrogen yields an intensely hot flame, but emits but a feeble light, because it contains no solid matter.

The gas employed for illuminating purposes is usually made from

coal, oil, resin, and other organic substances containing a large quantity of carbon and hydrogen. The coal is distilled in cast iron retorts, maintained at a bright red heat; and the volatilized products conducted through long pipes into receptacles where it is purified by means of hydrate of lime. Coal gas contains a number of different principles, as light carburetted hydrogen, olefiant gas, hydrogen, carbonic oxide, nitrogen, and some other volatile substances. Besides these, a number of other matters are separated in the processes of condensation and purification, as tar, sulphuretted hydrogen, sulphate of ammonia, &c. The relative illuminating power of different varieties of coal and oil gas depends upon the relative amount of carbon and hydrogen contained; the light being greatest when these are in excess, provided always, there be enough oxygen to burn them completely.

COMPOUNDS OF NITROGEN AND CARBON.

Cyanogen, Bicarburet of nitrogen, NC_2 or Cy. Prepared by heating in a retort the bicyanide of mercury; the cyanogen passes off in the form of a gas, and the mercury sublimes.

Prop.—Colourless, of a strong and peculiar odour; condenses into a liquid at 45° under a pressure of 3·6 atmospheres; a non-supporter of combustion, but inflammable, burning with a characteristic purple flame, producing water and carbonic acid. Water absorbs four or five times its volume, and alcohol much more;—sp. gr. 1·806.

Paracyanogen is the name given to the black matter left in the retort after the preparation of cyanogen.

Tests.—The peculiar odour; the *white* precipitate formed with silver; the blue compound obtained by heating it with an alkali and a persalt of iron.

Cyanogen and Hydrogen.—*Hydrocyanic acid, Cyanhydric acid, Prussic acid,* CyH. Prepared in the anhydrous form, by passing sulphuretted hydrogen over fragments of bicyanide of mercury, contained in a horizontal glass tube, and receiving the product in a vessel surrounded with a freezing mixture. Gentle heat is applied to the tube, and the cyanogen reacting with the sulphuretted hydrogen, produces hydrocyanic acid and the sulphuret of mercury.

Prop.—A thin, colourless liquid, exceedingly volatile; sp. gr. ·7058; boils at 79° and freezes at 0°; has a powerful characteristic odour of peach blossoms or oil of bitter almonds; has a very feeble acid reaction; unites with water and alcohol in all proportions. In its anhydrous state it is one of the most poisonous substances known. The best antidotes are chlorine and ammonia. It is very liable to decomposition, especially if exposed to the light.

The *solution* of hydrocyanic acid is best prepared by the action

of dilute sulphuric acid on the ferrocyanide of potassium. Also by the action of hydrochloric acid on the cyanide of silver.

Hydrocyanic acid is an organic product, being frequently met with in the vegetable kingdom. It is believed, however, not to pre-exist in vegetables, but to be due to the mutual reaction of two organic principles, named *amygdaline* and *emulsine* or *synaptase*, with water.

Cyanic Acid, CyO,—may be prepared from cyanate of potassa.

Prop.—A limpid, colourless liquid, with a pungent odour. With ammonia it forms a compound isomeric with *urea*.

Fulminic Acid, Cy_2O_2, is developed by the action of hyponitrous acid on alcohol in the presence of either silver or mercury. These *fulminates* are violently explosive.

CHAPTER II.

SECTION I.

METALS.

GENERAL PROPERTIES.

THEY are all conductors of heat and electricity; they are positive electrics; they are opaque; possess generally a well-marked lustre, termed *metallic;* and are generally good reflectors of light. The number generally admitted by chemists is forty-nine. Some of them are of very rare occurrence. They vary greatly in specific gravity, —between potassium, which is lighter than water, and platinum, which is twenty-one times heavier.

Properties which are peculiar to certain metals.—*Malleability, ductility, tenacity,* the *welding process, hardness,* and the *crystalline structure.*

All are solid at common temperatures, except mercury. Their fusing point varies very much—ranging between mercury, which is —39°, and platinum, which is infusible at the heat of a smith's forge.

Metals often unite together to form *alloys.* When mercury unites with another metal, the compound is named an *amalgam.* Examples of alloys are *brass*, from copper and zinc; *bronze*, from copper and tin; *bell-metal*, from copper and tin; *type-metal*, from antimony and lead; *solder*, from tin and lead. Gold and silver coins are also alloys. Many of the alloys occur native.

But few of the metals are found native, that is, in their uncombined form. They usually are united with either oxygen or sulphur, or else they occur as salts.

Metals differ greatly in their attraction for oxygen; some have such a powerful affinity for this agent, that they decompose water, in order to unite with it. On the other hand, gold, silver, and platinum are very difficult to oxidize. The term *noble* has been given to such metals as are not liable to tarnish on exposure to the air.

Most metals may be oxidized by exposure to heat in the open air. This process was formerly termed *calcination;* and the product formed a *calx*. Another mode of oxidizing is by *deflagration*, or by heating with nitrate of potassa, or chlorate of potassa. Nitric and nitro-hydrochloric acids are also powerful oxidizing agents.

Metallic oxides may be *reduced* either by heat alone, as in the case of the oxides of the noble metals, or by the united agency of heat and combustible matter, as hydrogen, charcoal, and the *black flux;* or by galvanism, which is still more powerful; or by the agency of deoxidizing agents, as phosphorous acid, protochloride of tin, &c.; or by precipitation from their solutions by means of other metals: thus silver is thrown down from a solution of its nitrate by means of mercury; copper, by means of iron, and so on.

The compounds of metals with oxygen, are for the most part *oxides;* occasionally they are *acids*. Arsenic is the only one which forms an acid, without, at the same time, forming an oxide. Most of the metallic oxides act as *salifiable bases*—that is, they form salts with acids. Generally, but not always, this property is confined to the *protoxides*.

Chlorine, bromine, iodine, and fluorine have also a strong affinity for metals,—particularly the two former.

Sulphur has a strong tendency to unite with metals : the combination may be effected either by heating the powdered metal and sulphur together; by igniting together a metallic oxide and sulphur; by heating a sulphate, along with combustible matter, by means of which the oxygen is removed in the form of carbonic acid ; or by the action of hydrosulphuric acid. Several of the metallic sulphurets (sulphides) occur native, as of lead, antimony, iron, zinc, &c.

The compounds of selenium and the metals closely resemble the sulphurets.

Phosphorus and hydrogen occasionally unite with the metals.

Before describing metals individually, it may be proper to bestow a few remarks on the subjects of *Salts* and *Crystallization*.

SECTION II.

SALTS.

THE term *salt* was formerly restricted to a compound of an acid and a salifiable base ; but this definition was necessarily vague, on

account of the difficulty of always accurately defining what was an acid, and what was a base. Formerly, an acid was considered to be an oxidized body which has a sour taste, reddens litmus, and neutralizes alkalies. Subsequent discovery showed the propriety of extending this definition; for, first, the discovery of the hydracids proved that oxygen is not essential to acidity; and secondly, some compounds, owing to their insolubility, have neither a sour taste, nor do they redden litmus, yet they neutralize bases; thirdly, there are some acknowledged acids, as carbonic, hydrocyanic, &c., which are unable fully to destroy the alkalinity of potassa.

Chemists of the present day agree to call all such bodies *acid* which unite with potassa or ammonia, and give rise to bodies similar in constitution and general character to the salts which sulphuric or some other admitted acid forms. For similar reasons, the present notion of what constitutes an alkaline or salifiable base, is that of a body which unites definitely with admitted acids, to form with them compounds resembling recognised salts.

There is a very important class of compounds, which, however, would not fall within the range of the above definition of a salt; and which yet have undoubted claims to be considered as such: they comprise the chlorides, iodides, bromides, &c., and are named *haloid* salts, from a Greek word signifying *sea salt*.

The notion of a salt has been still farther extended. It is known that two metallic sulphurets occasionally unite together to form a compound called a *double sulphuret*. To such compounds Berzelius gave the name of *sulphur-salts*. They are precisely analogous in their composition to a common oxy-salt, as may be seen by simply substituting for the sulphur an equivalent quantity of oxygen. In these salts, the *sulphur-acid* is a sulphuret of some one of the electro-negative metals, as arsenic, antimony, tungsten, &c.; the *sulphur-base* is a sulphuret of an electro-positive metal, as potassium, sodium, mercury, &c.

It has also been found that the haloid salts will unite together, to form what is termed a *double haloid salt;* which also may be considered precisely analogous to an oxy-salt, the halogen element (chlorine, iodine, &c.), simply taking the place of oxygen.

Thus we may make two generic divisions of salts into 1, *amphigen salts*, or those which are formed from amphigen bodies (oxygen, sulphur, selenium, and tellurium), and 2, *halogen salts*, or those containing a halogen body (chlorine, iodine, bromine, fluorine, and cyanogen).

By a *double salt* is meant one in which the same acid is united with two separate bases, as tartar emetic (tartrate of oxide of antimony and potassa).

Nearly all salts are solid at common temperatures; most are capable of crystallizing; their colour is variable; the soluble ones

are more or less sapid ; very few are odorous. They differ much in their affinity for water : some attract moisture from the air and become liquid ; such salts are called *deliquescent*. They differ also very much in their solubility in water, which is in the direct ratio of their affinity for water, and in the inverse ratio of their cohesion. In many salts water acts as a base, and is hence termed *basic water*.

As a general rule, every salt has its own distinct *crystalline form*, by which it may be recognised. Crystallization may be effected in various ways, as by solution and evaporation : the slower the evaporation, the larger and more regular the crystals ; if the evaporation be made very rapid by heat, a confused crystalline mass is obtained. Fusion and slow cooling may sometimes be employed ; thus crystals of sulphur and bismuth may be procured. A third condition under which crystals form, is in passing from the gaseous to the solid state, as in the case of iodine.

Many salts, in crystallizing, unite chemically with a definite portion of water, which belongs to the crystal, but not to the salt ; this is termed *water of crystallization*. By a strong heat, all this water is expelled, and the salt is said to undergo the *watery fusion*. Such salts, when exposed to the air, are liable to part with a portion of this water, and crumble down into a powder ; they are said then to be *efflorescent*. Others contain water even more intimately connected with them, and termed *constitutional water*.

Some salts, again, in crystallizing, enclose a portion of water mechanically within their texture ; which, by its expansion, when the salt is heated, causes it to burst with a crackling noise ; this is termed *decrepitation*.

Atmospheric pressure exerts an influence on the crystallization of salts ; if, for instance, a hot saturated solution of sulphate of soda be corked up in a bottle while the latter is full of vapour, the solution will cool down to the temperature of the air without crystallizing ; but on admitting the air, crystallization commonly commences, and the whole becomes solid in a few seconds.

Crystals are of various forms : they are divided by crystallographers into *simple* and *compound*. By *cleavage* is meant that property of a crystal by which it admits of being split in certain directions.

Bodies are said to be *isomorphous* when they have the same crystalline structure, but a different chemical composition : thus arseniate of soda is isomorphous with phosphate of soda. On the other hand, the same substance may have, under different circumstances, two crystalline forms ; in which case it is said to be *dimorphous* : sulphur and carbon are examples. The instrument employed to ascertain the angles of crystals is termed a *goniometer*.

SECTION III.

OXYSALTS.

This class of salts includes those, of which both the acid and base are oxides. It will be convenient to classify them according to their different acids.

SULPHATES.

Their solutions may always be recognised by yielding a white precipitate (sulphate of baryta), with a solution of a salt of baryta. Heated in contact with charcoal or hydrogen they are converted into sulphurets, which, if moistened, yield the peculiar odour of sulphuretted hydrogen. They are almost all insoluble in alcohol. The sulphates of baryta, tin, antimony, lead and bismuth, are quite insoluble in water. Those of lime, strontia, mercury, silver, and a few others, are nearly insoluble; while all the other sulphates are soluble.

The most important sulphates are those of potassa, soda, magnesia, lime, baryta, iron, copper, zinc, and mercury.

The most important *double sulphates* are the different *alums*. Common alum is a double sulphate of alumina and potassa. It may be prepared from native *alum stone*, in which the materials exist ready formed, or from a direct union of its constituents.

There are other varieties of alum, in which the sulphate of potassa is replaced by sulphate of soda, or sulphate of ammonia;—also *iron* and *manganese* alums, in which the sulphate of alumina is replaced respectively by the sulphate of iron and the sulphate of manganese.

The *Sulphites*, *Hyposulphites*, and *Hyposulphates*, are of very little practical importance.

NITRATES.

These may be prepared by the action of nitric acid on metals, —on the salifiable bases,—or on the carbonates. As they are soluble salts, their acid cannot be precipitated by any reagent. They are distinguished by deflagrating with charcoal, and other combustibles. When exposed to a high temperature, they are decomposed with the evolution of oxygen gas. If subjected to the action of sulphuric acid, they give off nitric acid fumes. When added to hydrochloric acid they form a solvent for gold leaf, by liberating the chlorine.

The most important nitrates are those of potassa, soda, ammonia, copper, mercury, and silver.

The *Nitrites* are comparatively unimportant.

CHLORATES.

These are very analogous to the nitrates. They are all decomposed by a red heat into metallic chlorides and oxygen gas. They deflagrate with combustibles even more violently than the nitrates. They are nearly all soluble in water.

The most important salt of this class is the *chlorate of potassa,* which is useful to the chemist in the preparation of oxygen.

The *Chlorites* are chiefly remarkable for their bleaching and oxidizing properties.

The *Hypochlorites* may be produced by the action of chlorine gas upon salifiable bases. The most important of them is the *hypochlorite of lime,* the well-known bleaching-powder, commonly called chloride of lime. It is prepared by exposing thin strata of recently-slaked lime to an atmosphere of chlorine : the chloride of calcium and hypochlorite of lime are formed.

IODATES.

These are compounds of iodic acid and a base. They bear a general resemblance to the chlorates, and may be recognised by the facility with which they are decomposed by deoxidizing agents, as hydrochloric, sulphurous, and phosphorous acids, which unite with the oxygen, setting iodine free.

The *Bromates* generally resemble the iodates.

PHOSPHATES.

As regards this class of salts, it is to be remembered that there are three isomeric phosphoric acids, termed *tribasic, bibasic,* and *monobasic,* or *phosphoric, pyrophosphoric,* and *metaphosphoric* acids. Each one of these modifications forms its own peculiar salts, the tests for which were spoken of under the head of Phosphorus. The most important phosphates are those of soda, lime, ammonia, lead, and silver.

CARBONATES.

These are distinguished by their facility of decomposition by any of the acids, with effervescence. All the alkaline carbonates are decomposable by heat, except those of potassa, soda, baryta, strontia, and probably lithia. All except those of potassa, soda, and ammonia, are sparingly soluble in water; but are more or less soluble in an excess of carbonic acds. Several of the carbonates occur native, as those of lime, magnesia, soda, baryta, iron, copper, and lead.

The most important carbonates are those of potassa, soda, lime, ammonia, magnesia, baryta, iron, copper, and lead.

ARSENITES AND ARSENIATES.

These are salts of arsenious and arsenic acids respectively. The

arsenites are all decomposed by a red heat, the arsenious acid being either dissipated in the form of vapour, or converted into arsenic acid.

The *arseniates* are not so easily decomposed, requiring usually along with heat the aid of charcoal, or black flux.

CHROMATES.

The salts of chromic acid are mostly of a yellow or red colour, the latter tint predominating whenever the acid is in excess. They are valuable as pigments. The most important of the chromates are those of potassa and lead.

BORATES.

The salts of boracic acid are very easily decomposed. The most important one is the *biborate of soda*, or common borax. They may all be recognised by their solutions in strong alcohol, burning with a greenish flame.

SECTION IV.

HYDROSALTS.

By this term is understood such salts, of which either the acid or base contains hydrogen. Formerly, this class of salts was much more extensive than it is at present, in consequence of the different views taken of the composition of the so-called *muriates*, or *hydrochlorates*, but which are now generally spoken of as chlorides. Indeed, all the haloid salts are now considered as compounds of the halogen element (chlorine, iodine, bromine, &c.) with a metal, rather than as compounds of a hydracid with the oxide of the metal, which was the former view. According to the present doctrine, when a hydracid is presented to any salifiable base, both are decomposed, water and a haloid salt of the metal being formed. Take hydrochloric acid and potash by way of example.

Hydrochloric acid { Chlorine ——————— Chloride of potassium.
                  { Hydrogen
Potash - - -   { Potassium
                  { Oxygen ——————— Water.
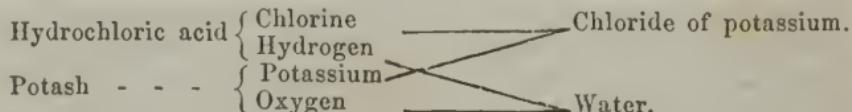
The only hydro-salts which are now at all recognised are the compounds of ammonia with a hydracid; though even these might be considered as haloid salts of the hypothetical metal *ammonium*. This will be evident by the following diagram :—

Hydrochloric acid { Chlorine — — — — — — Chlorine ⎫
                  { Hydrogen   ⎬ Sal ammoniac.
Ammonia - -   { 3 Hydrogen   ⎪
                  { Nitrogen ——————— Ammonium   ⎭
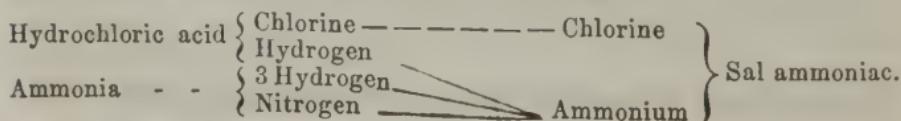
The most important of the ammoniacal salts are the *hydrochlorate*, commonly called sal ammoniac, and the *hydrosulphate*, formerly termed the *fuming liquor of Boyle*.

SECTION V.

SULPHUR SALTS.

THE sulphur salts are double sulphurets, just as the oxy-salts are double oxides; the sulphuret of one metal acting as an acid, while the sulphuret of another metal acts as a base. The sulphur salts are so constituted, that if the sulphur in both the acid and base was replaced by oxygen, an oxy-salt would result.

The principal *sulphur-bases* are, the protosulphurets of potassium, sodium, lithium, barium, strontium, calcium, and magnesium; and the principal *sulphur-acids* are the sulphurets of arsenic, tin, antimony, tungsten, molybdenum, tellurium, and gold, together with hydrosulphuric acid, and bisulphuret of carbon. Kermes' mineral, an important antimonial medicine, is an example of a sulphur salt, being composed chiefly of sulphuret of antimony, united with sulphuret of potassium.

SECTION VI.

DOUBLE HALOID SALTS.

THESE salts are composed of two simple haloid salts, one of which acts as an acid, and the other as a base, in a manner analogous to the double sulphurets. The principal groups consist of double chlorides, double iodides, and double fluorides.

When an oxide and chloride unite, they constitute a compound known by the name of *oxy-chloride*.

CHAPTER III.

CLASSIFICATION OF THE METALS.

CLASS   I. METALS OF THE ALKALIES.
CLASS II. METALS OF THE ALKALINE EARTHS.
CLASS III. METALS OF THE EARTHS.
CLASS IV. METALS PROPER.

SECTION I.

CLASS I.

METALS OF THE ALKALIES.

THE metals of the alkalies are *Potassium, Sodium, Lithium,* and *Ammonium.*

POTASSIUM.

Discovered in 1807 by Davy, by the agency of galvanism.—Prepared by exposing a mixture of carbonate of potash and charcoal to a high heat, in a gun-barrel; the potassium distils over, leaving carbonic oxide, thus :

1 eq. Carbonate of potassa $\begin{cases} K \\ O \\ CO_2 \end{cases}$

2 eq. Carbon, 2 C ————————————3 CO.
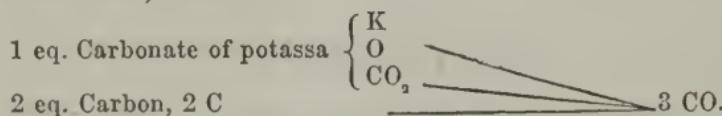
Prop.—Solid at ordinary temperatures,—soft and malleable between the fingers—of a white colour and metallic lustre—brittle at 32°,—melts at 150°; sp. gr. ·865,—has a powerful affinity for oxygen;—cannot be kept in the air or water;—preserved under naphtha or oil of copaiva. It takes fire when thrown on water, with the disengagement of hydrogen, which combines with a portion of the potassium, forming potassiuretted hydrogen, which also takes fire, increasing the brilliancy of the flame;—potash is formed as the result. The equivalent of potassium (Kalium) is 39·15; its Symbol, K.

It forms two compounds with oxygen, potash, KO, and the peroxide, KO_3.

Protoxide of potassium or *potash,* is formed whenever potassium is exposed to air or water. In the anhydrous form, it is a white solid, very caustic; has a strong affinity for water, with which it forms a hydrate.

The *hydrate of potassa,* KO+HO, also named *common caustic,*

and *potassa fusa*, is prepared by decomposing carbonate of potash by lime; the carbonate of lime is thrown down, and the potassa remains in solution; this is concentrated by heat, and then poured out into moulds. Pure hydrate of potassa is a white solid, very deliquescent, soluble in water and alcohol. The common caustic potash may be purified by dissolving in alcohol. The solution, like lime water, rapidly absorbs carbonic acid from the air. The solid hydrate, from its affinity for water, is used to free gases from hygrometric moisture.

Peroxide of potassium, KO_3, is formed when potassium is burned in dry oxygen, or in the open air; it is of an orange colour.

The most important salts of potassa are the *nitrates*, the *carbonates*, the *sulphates*, and the *chlorate*. The impure carbonate (*pot* and *pearl ashes*) is produced by lixiviating the ashes of inland plants, and evaporating to dryness; it is purified by redissolving in water, and boiling. The pure carbonate (salt of tartar) is made by decomposing cream of tartar by a high heat. Composition, $KO + CO_2$.

The *bicarbonate*, $KO + 2CO_2 + HO$, is formed by passing a stream of carbonic acid through a solution of the carbonate. It is not so soluble as the carbonate.—A *sesquicarbonate* is said to exist.

The *sulphate*, $KO + SO_3$, is the residue left in the retort in the preparation of nitric acid. The *bisulphate*, $KO + 2SO_3$, is more soluble, and has an acid taste and reaction. There is also a *sesquisulphate*.

The *nitrate*, $KO + NO_5$, named also *nitre* and *saltpetre*, occurs native, as an efflorescence on certain soils; it is manufactured also from artificial nitre-beds. Shape of crystals, six-sided prisms;—very soluble;—contains water mechanically confined, which causes the crystals to *decrepitate* when thrown upon hot coals. When heated, it gives off oxygen, and is converted into a *hyponitrite;* a high heat entirely decomposes it. From its power of imparting oxygen, it is the active ingredient in *gunpowder*, which is a mixture of nitre, charcoal, and sulphur. When gunpowder is fired, the oxygen of the nitre combines with the carbon to form carbonic oxide; the sulphur with the potassium; and the nitrogen is set free.

The *chlorate*, $KO + ClO_5$, is remarkable for its deflagrating properties; it yields a large quantity of oxygen gas, on being heated.

Silicate of Potassa.—$KO + SiO_3$.—Silicic acid unites in different proportions with the alkalies. If the base be in excess, a soluble salt is formed, called *liquor silicum;* if the acid be in excess, an insoluble salt (*glass*) is the result. Glass owes its colour to the different metals:—*green*, to the oxide of iron; *blue*, to cobalt; *ruby*, to red oxide of copper; *purple*, to the purple of Cassius; *amethyst*, to manganese, &c.

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Sulphur, chlorine, iodine, and bromine, also form compounds with potassium.

Chloride of Potassium, KCl, is obtained in making chlorate of potassa, by passing chlorine gas through a solution of potassa. It much resembles chloride of sodium.

Iodide of Potassium, KI, is made by dissolving iodine in a strong solution of caustic potash; also by adding iodide of iron to carbonate of potassa in solution; carbonate of iron is precipitated.

Tests for the salts of potassa.—1. Tartaric acid in excess gives the sparingly soluble bitartrate (cream of tartar). 2. A solution of chloride of platinum causes a yellow precipitate. 3. The alcoholic solution of carbazotic acid precipitates the yellow carbazotate of potassa. 4. The salts of potash usually colour the flame of the blowpipe purple or violet.

SODIUM.

Its history and mode of preparation are the same as those of potassium.

Prop.—A white metal; resembles potassium in most respects; sp. gr. ·972; decomposes water with great violence, but does not inflame on account of its rapid motion; if this be restrained by means of gum or sugar, it takes fire and is converted into *soda*. Eq.$=23\cdot3$; Symb. (Natrium), Na. It forms two compounds with oxygen, the *protoxide* (soda), Na O, and the *peroxide*, Na O_3; these are formed like, and correspond with, the analogous compounds of potassium.

Hydrate of soda, NaO + HO,—prepared from the carbonate by the action of quicklime. Very similar in its properties to the hydrate of potassa.

Carbonate of soda, NaO + CO_2 + 10HO. Prepared by lixiviating the ashes of marine plants, and evaporating; this is known under the commercial names of *barilla*, and *kelp*, which contain many impurities. A purer variety is made by heating together sulphate of soda, lime, and sawdust in a reverberatory furnace. Sulphuret of calcium, sulphurous acid, and carbonate of soda, are formed. This salt is in large rhombic crystals, very soluble in water, of a caustic alkaline taste, and alkaline reaction.

Bicarbonate, NaO + 2CO_2 + HO,—formed as the bicarbonate of potassa. It is less soluble than the carbonate.

Sesquicarbonate, 2NaO$_3$ + 3CO_2 + 4HO.—Occurs native.

Sulphate of Soda—Glauber's salt, NaO + SO_3 + 10HO; the residue left in the process for making hydrochloric acid. A very soluble salt; more so at 90° than at 212°.—There is also a *bisulphate*.

The *nitrate of soda* is very similar in properties to the nitrate of potash.—The three *phosphates* are spoken of under the head of Phosphorus.

Chloride of Sodium—*Common Salt*, NaCl,—is found in sea-water and saline springs; it occurs also as a mineral, under the name of rock salt; procured by evaporation from its solution. The crystals decrepitate when thrown on hot coals; they are very soluble in water, and are slightly deliquescent.—Iodine, bromine, sulphur, and fluorine, also combine with sodium.

Test for soda, and its salts.—All the soda salts are soluble; they communicate a yellow colour to the blowpipe flame. Soda forms with sulphuric acid, the well-known Glauber's salt. Soda is less soluble than potassa.

LITHIUM.

Prop.—A white metal resembling sodium;—procured by electrical action from *lithia*, its protoxide, which is found in petalite, and some few other rare minerals. The *hydrate of lithia* generally resembles the hydrates of soda and potassa, but is less soluble.

Test.—It communicates a carmine-red colour to the outer flame of the blowpipe.

AMMONIUM.

Ammonium is the hypothetical metal or radical of ammonia, which has already been treated of under the compounds of Hydrogen and Nitrogen. Its symbol is NH_4; that of ammonia (protoxide), NH_4O, or, NH_3,HO.

Carbonate of Ammonia, $NH_4O + CO_2$, is made by the union of carbonic acid and ammoniacal gas. The carbonate of the shops is a *sesquicarbonate*, and is made by subliming together carbonate of lime and chloride of ammonium.—There is also a *Sulphate* and a *Nitrate*.

Chloride of Ammonium, or *Sal Ammoniac*, NH_4Cl, is one of the products of preparing coal gas.

For the *tests*, see Ammonia.

SECTION II.

CLASS II.

METALS OF THE ALKALINE EARTHS.

THIS class includes Barium, Strontium, Calcium, and Magnesium.

BARIUM.

Procured by means of mercury from baryta or its carbonate, through the agency of galvanism, or heat.

Prop.—A grayish-white metal, heavier than water; has a strong affinity for oxygen; malleable.—Symb., Ba. It forms two oxides.

Protoxide, or *Baryta*, BaO.—Occurs in nature as a carbonate

and a sulphate;—may be obtained by decomposing the nitrate by heat. It has a strong affinity for water, forming with it a hydrate, with the evolution of heat. The hydrate is a white powder resembling slaked lime; its solution, like lime-water, attracts carbonic acid from the air.

Peroxide of barium, BaO_2, is used in making the peroxide of hydrogen.

The salts of baryta are chiefly remarkable for their high specific gravity; the most important are the carbonate, sulphate, and nitrate. The sulphate is very insoluble. The soluble salts are poisonous. Chlorine, iodine, bromine, and sulphur, form compounds with barium.

Test for baryta.—It forms a very insoluble *sulphate*.

STRONTIUM.

Procured as Barium.—Symb., Sr. It forms two oxides.

Protoxide,—Strontia, SrO,—prepared like baryta, which it much resembles. Its other compounds are similar to those of baryta.

Test.—It communicates a blood-red colour to the flame of the blowpipe.

CALCIUM.

A silver-white metal, procured like Barium;—forms with oxygen two compounds. Symb., Ca.

Protoxide, Lime, CaO,—obtained by heating the native carbonates.

Prop.—Lime is white,—infusible,—has a strong affinity for water, forming with it a solid hydrate, with the evolution of much heat; this is seen in the common process of *slaking.* The hydrate is far less soluble in water than those of baryta and strontia; it is more soluble in cold than in hot water; *lime-water* is thus made. Exposed to the air, it attracts carbonic acid, forming a pellicle; hence it is a good test for carbonic acid; it has an alkaline reaction. The hardening of mortar is probably due to the gradual absorption of carbonic acid, or to the combination of the sand and lime, forming a *silicate.*

The most important salts of lime are the sulphate, carbonate, phosphate, and hypochlorite.

Sulphate of lime or *Gypsum*, $CaO + SO_3$, is found native; the native crystals are called *selenite.*

Prop.—A sparingly soluble salt; forms with water a hydrate;—it is found in most spring water.

Carbonate of lime, Limestone, or *Chalk,* $CaO + CO_2$, is also found native.—The purest varieties constitute *marble.*

Prop.—Insoluble in water, but soluble if carbonic acid be present; exists in many natural waters, as a supercarbonate, and is deposited from them as *stalactites.*

The *phosphate* of lime exists in bones.

Chlorine, iodine, bromine, fluorine, and sulphur form compounds with calcium.

Chloride of calcium is prepared by the action of hydrochloric acid on carbonate of lime. It is distinguished for its great affinity for moisture, and hence is of great use to the chemist in removing water from substances; also used for forming frigorific mixtures. The *fluoride* is found native, as *fluor* or *Derbyshire spar*.

Hypochlorite of lime, commonly called *chloride of lime*, is the well-known bleaching-powder;—prepared by the action of chlorine on thin strata of hydrate of lime.

Test for lime.—Oxalic acid forms an insoluble *oxalate*.

MAGNESIUM.

Obtained by heating the chloride with potassium. It is a white, malleable metal; heated in the air, it is converted into magnesia.

Magnesia is the only oxide, MgO.—Prepared by driving off the carbonic acid from the carbonate, by heat. It is a soft, white, insoluble powder.

Carbonate of magnesia occurs native; may be easily prepared by double decomposition;—it is very nearly insoluble.

Sulphate of magnesia, Epsom salts, $MgO + SO_3 + 7HO$, exists in sea-water, and certain mineral springs; it is very soluble; forms crystals of a right rhombic prism.

Phosphates.—The most interesting is the *ammonio-magnesian phosphate*, or the triple phosphate, $2MgO + NH_4O, PO_5 + 14HO$. It sometimes constitutes urinary calculi.

Test for magnesia.—It forms the well-known Epsom salt with sulphuric acid.

SECTION III.

CLASS III.

METALS OF THE EARTHS.

THIS class includes Aluminium, Yttrium, Glucinium, Zirconium, Thorium, Erbium, Terbium, Norium, Cerium, Lantanum, and Didynium.

ALUMINIUM.

Prepared in the same manner as Magnesium. It has a gray colour; of difficult fusibility; forms alumina when burnt in the air.

Alumina is a sesquioxide, Al_2O_3; exists abundantly throughout nature, as a constituent of the different sorts of *clay*;—prepared by

adding carbonate of potassa to a solution of alum; the hydrate of alumina is precipitated.

Properties.—It has no taste or smell; feels pasty to the tongue; is very insoluble and infusible; has a strong affinity for water; acts but feebly as a base.

The most important salt of alumina is *alum*—a double sulphate of alumina and potassa, $Al_2O_3, 3SO_3+KO, SO_3+24HO$, manufactured from a native alum ore containing clay and sulphuret of iron. It crystallizes in octohedrons, is soluble in water, and is converted into *dried alum* by being deprived of its water by heat. Either soda or ammonia may be substituted for the potassa, in alum. The salts of alumina are useful as *mordants* in dyeing. Alumina forms the basis of porcelain and earthenware. *Tests for alumina.*—Caustic potash and soda give with it white gelatinous precipitates;—the well-known characteristics of *alum ;*—and the blue colour given by nitrate of cobalt by heat.

The remaining metals of the earths are of no particular importance.

SECTION IV.

CLASS IV.

METALS PROPER.

THIS class may conveniently be subdivided into three orders, viz., 1. Metals whose oxides form powerful bases; 2. Metals whose oxides form weak bases or acids; 3. Metals whose oxides are reduced by heat alone,—noble metals.

ORDER I.—METALS WHOSE OXIDES FORM POWERFUL BASES.

This order includes Iron, Copper, Zinc, Lead, Bismuth, Manganese, Cobalt, Nickel, Cadmium, Uranium, and Cerium.

IRON.

Very rarely occurs native;—exists in *meteorites*, combined with nickel and cobalt. As an oxide, it is widely diffused throughout nature. The most abundant ores of iron, are the oxides, and sulphurets, or *pyrites.* Some of the ores are magnetic, and some are not. Iron is extracted from its ores by roasting, and then exposing to a high heat, along with charcoal; by this means the common *cast iron* is procured; this is converted into *soft* or *malleable* iron by exposure to a strong heat, while a current of air plays upon its surface; by this means the carbonaceous matter is burnt off, and

the fusibility of the metal is diminished. *Steel* is a carburet of iron, formed by exposing alternate strata of soft iron and charcoal to an intense heat ; a direct union ensues, by which the iron acquires greater hardness.

Prop.—Iron has a peculiar gray colour—metallic lustre—not very malleable—quite ductile—the most tenacious of all metals ;—it is a hard metal—of a fibrous texture—sp. gr. 9·7—is very infusible—susceptible of the welding process—is attracted by the magnet—may itself be rendered magnetic by heating—does not oxidize in dry air at common temperatures ;—heated to redness, it becomes covered with a sealy coating of the black oxide—burns vividly in oxygen—rusts when exposed to air and moisture—decomposes water at a red heat, evolving pure hydrogen, and giving rise to the black oxide. *Chemically pure iron* may be procured by passing hydrogen gas over the sesqui or protoxide of iron heated to redness in a porcelain tube. It is sometimes called *pyrophoric iron ;*—it is used in medicine. Symb. (Ferrum), Fe.—Eq., 28.—It forms four compounds with oxygen.

Protoxide, FeO,—the base of the native carbonate, and of green vitriol. It can hardly be isolated, from its great proneness to absorb oxygen, and to pass into the state of sesquioxide ; the hydrate of the protoxide is formed when an alkali is added to a solution of the protosulphate ; it is of a dirty green colour, and speedily becomes red by the absorption of oxygen.

Peroxide (Sesquioxide), Fe_2O_3,—occurs in nature under the name of *red hematite ;*—made by dissolving iron in nitro-hydrochloric acid, and adding an alkali. *Prop.*—It is not attracted by the magnet ;—forms reddish salts with most of the acids. It can easily be detected by the infusion of galls, which gives with it a bluish-black precipitate, the basis of ink,—by ferrocyanide of potassium, which throws down *Prussian blue*,—by sulphocyanide of potassium, which causes a blood-red colour.

Black, or *Magnetic Oxide*, $FeO + Fe_2O_3$,—a mixture of the two former oxides ;—occurs native—is one of the most valuable of the ores ; it is the product of exposing iron to high heat. It does not form salts.

Ferric Acid, FeO_3,—only recently discovered—obtained by heating together one part of peroxide of iron with four parts of dry nitre, by which the ferrate of potash is formed; it is very difficult to isolate, on account of its extreme susceptibility to decomposition.

Iron forms two compounds with chlorine.

Protochloride FeCl,—formed by dissolving iron in chlorohydric acid, and drying.

Sesquichloride, Fe_2Cl_3, formed by the combustion of iron wire in chlorine gas.—There are also two *iodides ;* the protiodide is used in medicine, and is made by digesting iodine in water, with pure iron wire.

Sulphur unites with iron in several proportions.

Protosulphuret, FeS,—formed by heating iron and sulphur together; it has a blackish colour, and is attracted by the magnet. There is also a *Sesquisulphuret*, Fe_2S_3.

Bisulphuret, FeS_2, *iron pyrites*, exists native; it has a yellow colour and a metallic lustre; it is not magnetic.

Magnetic iron pyrites, is a native ore, consisting of a compound of the protosulphuret and bisulphuret (Stromeyer).

Cyanogen forms certain important double salts with iron.

Ferrocyanide of Potassium, or *Yellow Prussiate of Potash*, $FeCy_3$ $+2K$, is made by heating cyanide of potassium with iron; a compound radical—*ferrocyanogen*—is believed to be formed in the process, expressed by $FeCy_3$.

Ferrocyanide of Iron, *Prussian Blue*, $3FeCy_3+4Fe$, is made by adding ferrocyanide of potassium to a sesquisalt of iron.

Ferricyanide of Potassium, or *Red Prussiate of Potash*, Fe_2Cy_6 $+3K$.

Ferricyanide of Iron, or *Turnbull's Blue*, Fe_2Cy_6+3Fe.—These last two compounds contain a compound radical, *ferricyanogen*, Fe_2Cy_6.

The most important salts of iron are the sulphates, the carbonate, and the nitrate.

Protosulphate of iron, *green vitriol*, or copperas, FeO,SO_3, $HO+6HO$, is prepared by dissolving iron in sulphuric acid. It is crystalline—of a beautiful green colour—very soluble, and efflorescent. It is isomorphous with sulphate of magnesia. *Sesquisulphate* of iron,—made by the action of nitric acid on a solution of the protosulphate; it has a buff colour, and is sparingly soluble. There is only one carbonate—the *protocarbonate;* this is sometimes found native, and exists in chalybeate springs. There are two *nitrates*.

The best *tests* for iron, are those mentioned under the head of the sesquioxide.

<center>COPPER.</center>

Occurs sometimes in native crystals; but, most commonly, as a sulphuret, from which the metal is extracted by roasting with charcoal.

Prop.—The only red metal except titanium; has considerable lustre; sp. gr. 8·6; is very ductile, malleable, and tenacious; undergoes but little change in dry air; but, when moist, it is converted into a subcarbonate. Symb. (Cuprum), Cu.—Eq., 31·6. Copper forms two or three oxides.

Dioxide, or *red oxide*, Cu_2O, occurs native, in octohedral crystals. It may be formed by heating together the protoxide and copper filings. It forms colourless salts with bases, which, however, are very unstable, from their tendency to absorb oxygen.

Protoxide or *black oxide,* CuO, the basis of most of the salts of copper:—prepared by calcining metallic copper:—by precipitating from any salt by an alkali;—and by heating the nitrate. Its colour varies from a dark brown to a black. There is also a *binoxide.*

There are two *chlorides, iodides,* and *sulphides* of copper, similar in composition to the first two oxides.

The most important salts of copper are the *sulphate, nitrate, carbonates,* and *acetates.* The sulphate—well known in commerce, as *blue vitriol*—is formed by the action of sulphuric acid on copper. The carbonate occurs native, in the mineral *malacite. Verdigris* is composed of one or more of the acetates of copper.—The proper solvent of copper is nitric acid.

Tests.—Ammonia, in small quantities, throws down from a solution of the sulphate, the bluish-white hydrated protoxide; but when added in excess, it redissolves the precipitate, forming a deep blue colour. Ferrocyanide of potassium gives a fine reddish-brown ferrocyanide of copper.—It is also precipitated upon iron or steel. Copper forms several important alloys, such as *brass,* with zinc; *bell metal,* with tin; and *bronze,* with zinc and lead.

LEAD.

Procured chiefly from the native sulphuret or *galena,* by roasting, which converts most of it into a sulphate; the sulphate and sulphuret reacting upon one another, produce sulphurous acid, and metallic lead.

Prop.—A soft, bluish metal; has a metallic lustre when freshly cut; somewhat malleable and ductile, particularly in the form of pipes; not very tenacious: sp. gr. 11·45; melts at 600° F. Exposed to moist air, it becomes coated with a film of the dioxide; also absorbs oxygen when heated in the open air. Symb. (Plumbum), Pb. Eq., 103·6.—It forms four oxides.

Dioxide, Pb_2O, formed by heating dry oxalate of lead in a retort; it absorbs oxygen very rapidly.

Protoxide, PbO, the basis of the salts of lead, is prepared by exposing the gray film which collects on the surface of melted lead, and which consists of the protoxide and metallic lead, to a high heat, with the access of air; this constitutes the *massicot* of commerce; when partially fused by heat, it becomes *litharge;* in this state it contains some peroxide. It has a yellow colour, is insoluble in water, unites with acids, forming salts, from which it is precipitated by alkalies as a hydrate, and as *white lead* by alkaline carbonates.

Peroxide, puce, or *brown oxide,* PbO_2, prepared by the action of nitric acid on red lead, which converts it into the protoxide and peroxide. It has a flea-colour, and is insoluble; by heat it is converted into protoxide, and oxygen.

Red lead, or *minium,* Pb_3O_4, or $2PbO+PbO_2$, considered to

be a compound of the protoxide and peroxide; is formed by exposing lead to heat in the air, without allowing it to fuse. It is a heavy, brilliant red powder; decomposed, with the evolution of oxygen, by a strong heat; and converted into a mixture of protoxide and peroxide by acids. It is used as a pigment, and in the manufacture of flint-glass.

Chlorine forms with lead a compound known as *plumbum corneum*, or horn lead. Sulphur forms with lead the well-known *galena*, which occurs in cubical crystals. Iodine, bromine, fluorine, and phosphorus also form compounds with lead.—The most important salts of lead are the *carbonate* and *acetate;* also the nitrate and sulphate.

Carbonate of lead, White lead,—is sometimes found in a native crystalline state; may be prepared by precipitating from any soluble salt of lead by means of an alkaline carbonate;—is manufactured by exposing sheet-lead in coils to the action of the vapour of vinegar, at the temperature of decomposing manure : the lead is oxidized by the partial decomposition of the acetic acid, and is then converted into the subacetate. This salt is next decomposed by carbonic acid escaping from the manure in which the lead is packed. It is a soft, white, very heavy powder, insoluble in water; it is much used as a pigment.

Acetate of lead, Sugar of lead,—made by dissolving litharge in acetic acid; occurs in colourless, transparent crystals; has a sweet taste; is very soluble in water, also in alcohol.—There are several *subacetates* of lead, made by boiling a solution of the acetate in litharge.

Nitrate of lead, prepared by the action of nitric acid on lead. Nitric acid is the proper solvent of lead;—it is soluble.

Sulphate of lead, prepared by the action of a soluble sulphate on a solution of the acetate of lead; it is a very insoluble salt. Cold sulphuric acid has no action on lead; but when boiling, the lead is slowly oxidized at the expense of the acid. Hydrochloric acid has no action on lead.

Tests.—The alkaline carbonates throw down the insoluble carbonate; the soluble sulphates throw down the insoluble sulphate; sulphuretted hydrogen, or a soluble hydrosulphate, throws down the black sulphuret; chromate of potassa gives the yellow chromate of lead; and iodide of potassium yields the yellow iodide of lead.

ZINC.

Occurs in nature as a carbonate (*calamine*), or as a sulphuret (*zinc blende*). It is procured from the former by heat and charcoal; and from the latter by a similar process, after roasting the ore; at a high temperature, the metal, being volatile, comes over by distillation.

Prop.—A bluish-white metal; has a crystalline texture; sp. gr. 7; brittle at common temperatures; malleable between 250° and 300°; very brittle at 400°; melts at 773°, and at a bright red heat it boils and burns with a brilliant green light, generating the oxide. It is called *spelter* in commerce, and is never quite pure; is slightly tarnished by exposure to the air. Symb. (Zincum), Zn. —Eq., 33.

Oxide of Zinc, ZnO ;—prepared by burning zinc in the air, or by heating the carbonate. It is a white, insoluble powder, the basis of the salts of zinc.

Chloride of Zinc, ZnCl ;—prepared by heating metallic zinc in chlorine, or by dissolving zinc in hydrochloric acid, and drying. It is a white substance, has the consistence of butter, and is hence called *butter of zinc;* very deliquescent, and soluble in water and alcohol.

The important salts of zinc, are the sulphate and the carbonate.

Sulphate of Zinc, white vitriol ;—made by acting on zinc with dilute sulphuric acid; the water is decomposed, its oxygen going to the zinc, and the hydrogen escaping. It is a white, crystalline, soluble salt.

Carbonate of Zinc,—occurs native, and may be formed by double decomposition between any soluble carbonate and the sulphate of zinc.

CADMIUM.

This metal is usually found associated with zinc, in the reduction of which from its ores, the cadmium, being more volatile, flies off.

Prop.—It resembles tin in colour; very malleable; very volatile; sp. gr. 8·7; melts below 500°; when strongly heated, it burns, forming the *oxide.*

BISMUTH.

Occurs both native and in combination; it may be procured pure by heating the subnitrate with charcoal.

Prop.—A crystalline metal, of a reddish-white colour and metallic lustre; when slowly cooled, it yields cubical crystals; fuses at 476°, and in close vessels sublimes unchanged; in the open air burns with a bluish flame, and is converted into the *oxide;* its proper solvent is nitric acid. It forms two oxides. Sp. gr. 10.—Eq., 71.

Protoxide, BiO ;—the basis of all the salts, has a yellow colour; obtained by heating the subnitrate. *Peroxide*, Bi_2O_3 ;—Bismuth unites also with chlorine and sulphur.

Nitrate of Bismuth ;—made by dissolving the metal in nitric acid, and evaporating. This, when thrown into water, is decom-

posed into the soluble *supernitrate*, and the insoluble *subnitrate*, which subsides as a white powder.

The best *test* is the formation of the subnitrate; also sulphuretted hydrogen.

MANGANESE.

Is found in nature as an *oxide;* procured from this by intensely heating with charcoal.

Prop.—A hard, brittle metal, of a grayish-white colour, very infusible, sp. gr. about 8; forms *seven* compounds with oxygen, viz.: Protoxide, MnO, Sesquioxide, Mn_2O_3, Peroxide, MnO_2, Red oxide, Mn_3O_4, Varvicite, Mn_4O_7, Manganic acid, MnO_3, Permanganic acid, Mn_2O_7. The most important of these, to the chemist, is the peroxide, or black oxide, which occurs abundantly in nature. It is used in the arts, in the manufacture of glass; and by the chemist for procuring chlorine, bromine, and oxygen.

The best *test* for manganese is the play of colours—called the *mineral chameleon*—produced by dissolving manganate of potassa in water. Manganic acid cannot exist uncombined. The changes of colour are owing to the formation of the *permanganate of potassa,* which is red, and the mixture of red and green produces the intermediate colours.

NICKEL AND COBALT.

These two metals strongly resemble each other: both occur in combination with arsenic. Nickel is found associated with meteoric iron, and is strongly magnetic. Cobalt is not so. Both have a white colour. Nickel is malleable; Cobalt is brittle. Nickel is employed in the arts, in the preparation of *German silver*—an alloy of copper, zinc, and nickel.

The best *test* to distinguish cobalt from nickel, is the fine blue colour communicated by the former to the flame of the blowpipe, when fused with borax.

URANIUM AND CERIUM.

These are very rare metals, and are of no practical use.

SECTION V.

ORDER II.—METALS WHOSE OXIDES FORM WEAK BASES, OR ACIDS.

THIS order includes Tin, Antimony, Arsenic, Chromium, Vanadium, Tungsten, Molybdenum, Columbium, Titanium, Tellurium, and Osmium.

T I N.

Is found in nature as an *oxide*, from which it may be procured by heating with charcoal. The varieties known in commerce are *block* and *grain tin*.

Prop.—Has a white colour, silvery lustre, is very slowly tarnished by exposure to the air; very malleable, quite ductile, soft, and inelastic, and produces a crackling noise when bent backwards and forwards; sp. gr. about 7; fuses at 442°; heated to whiteness, it burns, and is converted into the peroxide. Symb. (Stannum), Sn. —Eq. 58. It forms three oxides.

Protoxide, SnO;—formed by adding an alkaline carbonate to a solution of the protochloride; a white hydrated protoxide falls.

Sesquioxide, Sn_2O_3,—has a grayish colour.

Peroxide, SnO_2;—prepared either by precipitating by an alkali from a solution of the perchloride, or by the action of nitric acid on metallic tin. Very strong nitric acid has no effect on tin; but, if diluted, violent effervescence ensues from the escape of nitrous acid and binoxide of nitrogen, and the hydrated peroxide is produced; ammonia is also generated at the same time, the hydrogen being furnished by the water.

Protochloride, SnCl,—made by dissolving tin in hot hydrochloric acid; occurs in crystals. It is much used as a deoxidizing agent.

Perchloride, $SnCl_2$, called the *fuming liquor of Libavius;*—made by heating the protochloride, or metallic tin, in chlorine; it is a very volatile, colourless liquid, emitting dense white fumes on being exposed to the air; it is used as a *mordant* in dyeing.

There are three sulphurets of tin—the *protosulphuret, sesquisulphuret,* and *bisulphuret;* the latter is sometimes termed *mosaic gold.*

Test.—Solution of chloride of gold throws down, with the protochloride of tin, the *purple of Cassius.*

A N T I M O N Y.

Occurs in nature generally as a *sulphuret,* which, in commerce, is called *crude antimony,* while the pure metal is named *regulus of antimony.* It may be obtained from the sulphuret by heating it with iron filings.

Prop.—A bluish-white colour—crystalline structure—brittle—sp. gr. 6·8;—at a high temperature it burns in the open air, the vapour condensing in white crystals of the teroxide (*argentine flowers of antimony*); it is acted upon by both nitric and hydrochloric acids. Symb. (Stibium), Sb.—Eq., 129. It forms three compounds with oxygen.

Teroxide, SbO_3,—prepared by burning antimony in the open air, —by precipitation from a solution of tartar emetic by means of an

alkaline carbonate, or by the action of carbonate of potassa or soda
on the terchloride, when put into water. It is a pale yellow powder
—volatile—liable to absorb oxygen. It is the basis of all the anti-
monial salts.

Antimonious acid, SbO_4,—made by heating the oxide in open
vessels;—a grayish-white powder—insoluble—combines with alka-
lies.

Antimonic acid, SbO_5,—made by action of strong nitric acid in
antimony; an insoluble straw-coloured powder; unites with alka-
lies, to form *antimoniates*.

Terchloride, $SbCl_3$ (*butter of antimony*),—made by burning
antimony in chlorine gas; a soft solid at common temperatures;
when put into water, hydrochloric acid and the sesquioxide are
generated, and the latter, combined with some undecomposed chlo-
ride, subsides as the *powder of Algaroth*. There are one or two
other chlorides.—There are several *sulphurets*, of which the most
important is the native *tersulphuret;* it is a lead-gray substance,
brittle, and fusible. It may be made by melting sulphur and
antimony together, or by passing sulphuretted hydrogen through a
solution of tartar emetic. There are also a *pentasulphuret* and a
pentachloride.

Kermes mineral.—Prepared by boiling tersulphuret of antimony
in a solution of caustic potassa; a partial double decomposition
ensues, by which an oxide of antimony, and a sulphuret of potas-
sium are formed; the latter unites with undecomposed sulphuret of
antimony to form a sulphur-salt, in which the sulphuret of antimony
is the acid, and sulphuret of potassium the base. As the solution
cools, this double salt becomes decomposed, the tersulphuret of
antimony subsiding along with a variable portion of potassa and
oxide of antimony. This is the *kermes*, which may hence be con-
sidered as an *oxy-sulphuret*. The mother waters still contain some
of the above sulphur-salt, together with potassa and oxide of anti-
mony; and, on the addition of sulphuric acid, the teroxide and
tersulphide are precipitated together, but without the potassa; this
is the *golden sulphuret*.

The most important salt of antimony is *tartar emetic;*—made by
boiling cream of tartar with the teroxide of antimony. It is a
white, crystalline, soluble salt, which gives a brick-red precipitate
(the tersulphuret) with sulphuretted hydrogen; it also yields pre-
cipitates with the alkalies, earths, tannic acid, &c. It is a neutral
bibasic salt—tartrate of antimony and potassa,—the oxide of anti-
mony merely substituting the water in the cream of tartar (tartrate
of potassa and water).

ARSENIC.

Is sometimes found native, but is generally procured from the
native arseniuret of cobalt and nickel, by means of heat.

Prop.—A steel-gray colour; metallic lustre; very brittle; tarnishes in the air; sp. gr. 5·9; volatilizes by heat, and, if air be present, is converted into arsenious acid; its vapour has the odour of garlic. Symb., As.—Eq., 76·4. It forms two well-known compounds with oxygen, *arsenious,* and *arsenic* acids; but no basic compound.

Arsenious acid, white oxide of arsenic, fly powder, AsO_3,—is always generated when arsenic is heated in the open air; that of commerce is derived by roasting the native ores of cobalt. It is quite transparent and glassy when first prepared, but becomes opaque by exposure; volatile at 380°; vapour is inodorous, and condenses on cool surfaces; not very soluble in water; reddens vegetable blues feebly; combines with bases, forming *arsenites;* it has an acid taste, and is very poisonous.

Arsenic acid, AsO_5,—made by dissolving arsenious acid in strong nitric acid, mixed with a little hydrochloric acid, and evaporating to dryness. It is sour to the taste; much more soluble in water than arsenious acid; forms *arseniates;* is isomorphous with phosphoric acid; when strongly heated, it is converted into arsenious acid and oxygen.

There are three well-known sulphurets of arsenic.

Bisulphuret or *Realgar,* AsS_2, occurs native;—may be made by heating together sulphur and arsenious acid; colour, ruby-red.

Tersulphuret or *Orpiment,* AsS_3, is also found native;—made by transmitting sulphuretted hydrogen through a solution of arsenious acid: colour, yellow,—called *king's yellow.*

Pentasulphuret, AsS_5, made by action of sulphuretted hydrogen on a solution of arsenic acid; it resembles orpiment in colour. The sulphurets are poisonous.

Arsenic also unites with chlorine, iodine, &c.

Arseniuretted hydrogen, AsH_3, prepared by adding arsenious acid to the materials for generating hydrogen; colourless; odour of garlic; sp. gr. 2·6; burns with a blue flame, generating arsenious acid; a non-supporter of combustion; very poisonous when breathed; slightly soluble in water.

Tests for arsenic.—1. Ammoniacal nitrate of silver (made by adding ammonia to a solution of nitrate of silver, until the oxide of silver, which is thrown down, is nearly all dissolved); arsenious acid added to this, throws down the insoluble arsenite of silver of a yellow colour.

2. *Ammoniacal sulphate of copper* (made by adding ammonia to a solution of sulphate of copper), throws down, with arsenious acid, the insoluble arsenite of copper (*Scheele's green*).

3. *Hydrosulphuric acid*, when transmitted through a solution of arsenious acid, precipitates the tersulphuret (orpiment).

4. The production of *arseniuretted hydrogen.*—By adding the

matter containing arsenic to the materials for generating hydrogen, on burning a jet of this gas, and holding over it a piece of glass or porcelain, an *arsenical ring* is formed.—None of the above tests can be relied on singly. The best method is to *reduce* the arsenic by means of heat and charcoal (or black flux), in a glass tube; by which means the arsenical ring may always be produced, and the peculiar odour of burning arsenic be detected. The proper antidote for arsenic is the *hydrated peroxide of iron*, in a moist state.

The remaining metals of this order are Chromium, Vanadium, Tungsten, Molybdenum, Columbium, Titanium, Tellurium, and Osmium. None of them are of practical importance except *chromium*, two salts of which are much used in the arts, viz. : *chromate of lead* (chrome yellow), and the *bichromate of potash*. Chromic acid is remarkable for the facility with which it parts with oxygen; it is, therefore, much used in organic analysis.

SECTION VI.

ORDER III.—METALS WHOSE OXIDES ARE REDUCED BY HEAT.

GOLD.

Occurs either pure, in union with quartz, or combined with silver or copper. It is usually separated from impurities by amalgamation with mercury, which is afterwards driven off by heat. From silver it is separated by the process of *quartation*, which consists in adding to the alloy so much silver as to make the latter constitute three-fourths of the mass; in which case the whole of the silver may be removed by nitric acid. May be obtained pure by dissolving in nitro-muriatic acid, and then precipitating by a protosalt of iron.

Prop.—It has a well-known yellow colour ; is the most malleable, and one of the most ductile of all metals ; is not tarnished by either air or moisture ; sp. gr. 19·3. Symb. (Aurum), Au. The only solvent for gold is a mixture of nitric and hydrochloric acids, or rather, the solution of chlorine which thence results. An etherial solution of gold is made by agitating ether with the strong aqueous solution ; this may be used for gilding. If *protochloride of tin* be added to the solution of gold, the *purple powder of Cassius* is thrown down. Gold forms compounds with oxygen, chlorine, iodine, and sulphur.. Gold coins are always alloyed with copper or silver, which increase its hardness. The best *test* for gold is the protochloride of tin.

SILVER.

Occurs native, and in combination with gold, and other metals; also with chlorine, and sulphur. One of the most abundant silver ores is the *argentiferous galena*. It is extracted either by amalgamation, or by *cupellation*,—the latter process being only applicable to the combinations with lead. Pure silver may be procured by precipitation from a solution in nitric acid, by means of chloride of sodium, and heating the resulting chloride with carbonate of soda.

Prop.—The whitest of all metals; has a brilliant lustre; is very malleable and ductile; the best conductor of heat and electricity; sp. gr. 10·5; is not acted upon by moisture or air, unless sulphur be present; its proper solvent is nitric acid; Symb., Ag. It forms two or three oxides, of which the protoxide acts as a base. The most important salt is the *nitrate*, or *lunar caustic*,—made by dissolving silver in nitric acid, and evaporating. The crystals are colourless; very soluble in water; the solution becomes dark-coloured when exposed to light, in contact with organic matter, probably from the formation of an oxide.

The *arbor Dianæ* is made by suspending mercury in a solution of the nitrate: the silver is precipitated in the form of crystals. It is also precipitated by the chlorides, phosphates, chromates, arseniates, arsenites, and several of the metals.

The best *test* is chlorine, or a soluble chloride.

Silver forms compounds with chlorine, iodine, and sulphur.

PLATINUM.

Occurs only in the metallic state, generally combined with other metals, particularly palladium, osmium, rhodium, and iridium. It is found in grains, which are converted into masses by intense heat and pressure.

Prop.—It has a whitish colour; very malleable; the most ductile of metals; the heaviest body in nature; sp. gr. 21·5; is soft; can be welded, like iron; undergoes no change by exposure to air, moisture, or the highest heat of a smith's forge; it can only be fused by galvanism or the oxy-hydrogen blowpipe; it is dissolved by nitromuriatic acid. In its habitudes with oxygen, chlorine, and sulphur, it resembles gold.

Spongy platinum has the singular property of causing the union of oxygen and hydrogen gases, producing combustion. This is probably due to the intimate molecular relationship into which the two gases are brought in the pores of the metal.

Tests.—A solution of chloride of potassium produces with chloride of platinum a double chloride, of a pale yellow colour; sal ammoniac gives with it a yellow precipitate, which, by heat, yields spongy platinum.

The other metals associated with platinum (Palladium, Osmium, Iridium, and Rhodium), need no particular description.

MERCURY OR QUICKSILVER.

Occurs in the metallic state; but more frequently as a sulphide or chloride;—extracted by heat, which sublimes the mercury.

Prop.—The only metal fluid at ordinary temperatures;—has a silver-white colour, and brilliant lustre; becomes solid at —39°, when it is malleable; boils at 662°;—sp. gr. 13·6; that of frozen mercury, about 14. Pure mercury is not altered by the air at common temperatures, but absorbs oxygen when heated. Hydrochloric acid has no action, nor sulphuric acid, unless concentrated and boiling; nitric acid, even when cold and dilute, acts upon it, forming a nitrate.

Mercury forms two oxides, the *black* and the *red*. The eq. is 202 (Turner, Hare), or 101 (Graham, Kane, &c.) The nomenclature of the different compounds will, of course, depend upon the adoption of either one of these.

Protoxide, HgO (suboxide, Hg_2O).—Prepared by action of caustic potash, or lime, on a solution of the nitrate, or on calomel; it is a dull gray powder, insoluble in water;—decomposed, by the action of light, into the red oxide, and metallic mercury.

Peroxide, HgO_2 (protoxide, HgO), *red oxide*.—Prepared by the combined agency of heat and air; by heating the nitrate; or by precipitation from a solution of corrosive sublimate, by means of potassa. It is often called *red precipitate*. It is in the form of fine red shining scales, very slightly soluble in water; converted by heat into metallic mercury, and oxygen.

Chlorine forms two compounds, *calomel* and *corrosive sublimate*.

Protochloride, or calomel, $HgCl$ (subchloride, Hg_2Cl). Prepared either by *precipitation*, by means of chloride of sodium in a solution of the nitrate; or by subliming together the protosulphate of mercury and chloride of sodium. The rationale is as follows:—


```
Protosulphate of ⎧ Mercury  ──────────── Calomel, HgCl.
    mercury      ⎨ Oxygen
                 ⎩ Sul'c acid  ──┐   ┌──
Chloride of so-  ⎧ Chlorine   ───┘   └──
    dium         ⎨ Sodium  ────────────── Sulphate of soda.
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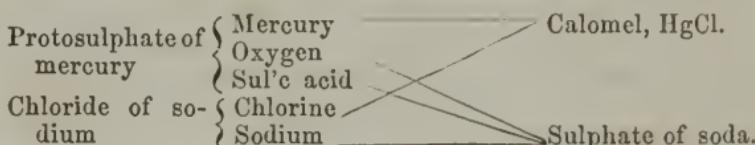
As prepared by ordinary sublimation, calomel occurs in yellowish-white masses; but if the vapour be conducted into a recipient containing watery vapour, it is condensed in a very fine white powder. It is insoluble, tasteless; sp. gr. 7·2; is apt to contain a little corrosive sublimate, which can be removed by washing, or throwing down by ammonia. Potassa or lime decomposes it, throwing down the black oxide.

Bichloride, or *corrosive sublimate,* $HgCl_2$ (protochloride, $HgCl$).—

Prepared by burning mercury in chlorine gas; by action of hydrochloric acid on the red oxide; or preferably, by subliming together the bisulphate with common salt, thus :—

1 eq. bipersulphate of mercury	Mercury 2 Oxygen 2 Sul'c acid	Bichloride of mercury, $HgCl_2$.
2 eq. chloride of sodium	2 Chlorine 2 Sodium	2 eq. sulphate of soda.
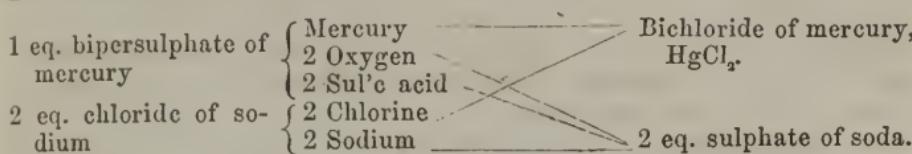
Prop.—Crystalline ; soluble in water, alcohol, and ether. The alkalies and their carbonates throw down from it the red oxide ; ammonia in excess throws down from its solution the *white precipitate*, which is considered to be an *amo-chloride* of mercury (Kane). This amo-chloride, or *chloramide*, as it is often called, is considered to be a double salt, composed of the *biamide* of mercury and some undecomposed *bichloride.*—*Albumen* is the best antidote for it.

There are two iodides, two bromides, one cyanide, and two sulphides of mercury. The bisulphide occurs native, under the name of *cinnabar ;* its powder is called *vermilion. Ethiop's mineral* is made by triturating mercury and sulphur together, until the globules disappear ; it is considered to be a mixture of sulphur and the bisulphide.

The most important *salts* are formed with nitric and sulphuric acids, each of which unites with the protoxide and the peroxide. The *turpeth mineral* is the subsulphate, formed by throwing the sulphate into water.

The best *tests* for mercury are :—iodide of potassium, which gives with a protosalt the *green* iodide, and with a persalt, the beautiful *red* biniodide ;—protochloride of tin gives a black precipitate if heated with a protosalt ;—a drop of a mercurial solution put upon a polished surface of gold, and touched with the point of a penknife, instantly causes a white stain, from the amalgam which is formed by the galvanic agency.

PART III.

ORGANIC CHEMISTRY.

GENERAL OBSERVATIONS.

ORGANIC substances, whether derived from the vegetable or animal kingdom, are chiefly remarkable for the complexity of their composition, and for the limited number of their elements. Only *four* elements are considered essential to the composition of organic

matter, viz., carbon, oxygen, hydrogen, and nitrogen,—though others are occasionally met with, as sulphur, phosphorus, chlorine, sodium, &c.; altogether they do not amount to more than fifteen. There appears, however, to be no limit to the number of definite compounds which may be produced out of merely the four above-named essential elements, simply by a difference in their proportions and mode of arrangement.

In consequence of the complexity of organic bodies, they are generally very instable, being prone to decomposition whenever the restraining force is removed. The products of such decomposition are water, carbonic acid, and ammonia; and if sulphur be present, sulphuretted hydrogen.

As a general rule, the more complex is the constitution of an organic body, the more liable is it to decomposition; but this tendency is much lessened if the elements are in such proportions as completely to *saturate* each other; thus, in sugar, starch, and lignin, the proportions of oxygen and hydrogen are exactly sufficient to saturate each other, and to form water.

Vegetable organic matter is usually *ternary* in its composition, and is not so prone to decomposition as animal organic matter, which is generally *quaternary*. Both are invariably decomposed by heat.

Isomeric bodies are frequently met with among organic substances. By this term is meant bodies having the same chemical composition, but possessing very different properties; starch, sugar, and gum are examples. Isomerism is believed to depend upon a *different arrangement* in the constituent atoms of a body,—their number remaining the same.

SECTION I.

OF COMPOUND RADICALS.

By the term *compound radical*, is meant a substance which, although containing two or more elements, acts precisely as a simple elementary body. The following are the most important of the admitted compound organic radicals, together with their chemical composition expressed in symbols.

	Formula.
Carbonic oxide, or protoxide of carbon, - - -	CO.
Cyanogen, or bicarburet of nitrogen, - - -	C^2N.
Mellon, or sesquicarburet of nitrogen, - - -	C^9N^4.
Benzoile, benzule, or benzyle, - - - -	$C^{14}H^5O^2$.
Cinnamyl, or cinnamule, - - - - -	$C^{16}H^8O^2$.
Salycyle, or salicule, - - - - -	$C^{14}H^5O^4$.
Acetyle, or acetule, - - - - -	C^4H^3.

Formyle, or formule,	-	-	-	-	-	-	C^2H.
Amide,	-	-	-	-	-	-	NH^2.
Ethyle, or ethule,	-	-	-	-	-	-	C^4H^5.
Methyle, or methule,	-	-	-	-	-	-	C^2H^3.
Cetyle, or cetule,	-	-	-	-	-	-	$C^{32}H^{33}$.
Glyceryle, or glycerule,	-	-	-	-	-	-	C^6H^7.
Amyle, or amule,	-	-	-	-	-	-	$C^{10}H^{11}$.
Mesetyle, or mesetule,	-	-	-	-	-	-	C^6H^4.
Kacodyle, or kacodule,	-	-	-	-	-	-	C^4H^6As.

Besides these, there are some subordinate compound radicals. A few of the above radicals will be noticed now; the others will be spoken of when their compounds come under consideration.

Amide, NH_2, or amidogen. This compound radical is believed to be generated when ammonia is heated in contact with potassium or sodium; hydrogen is liberated, and a compound formed of amyde and the metal. When the amyde of potassium or sodium thus generated is put into water, this liquid forms ammonia by yielding up hydrogen to the amyde; and at the same time it converts the potassium into potash, by giving up its oxygen. According to this view, ammonia is an amyde of hydrogen. Ammoniated mercury (white precipitate) is a compound of an amyde and the bichloride of mercury.

Carbonic oxide, CO, has already been spoken of as a compound of carbon. By combining with carbonic acid, CO_2, it constitutes *oxalic* acid, C_2O_3. The most important compounds of this radical are *carbamide, oxamide,* and *chloroxycarbonic* acid, a compound of carbonic oxide and chlorine.

Benzule or *Benzyle*, $C_{14}H_5O_2$,—the hypothetical radical of benzoic acid, and of the oil of bitter almonds. By the addition of an atom of oxygen and an atom of water, it forms benzoic acid. By substituting an atom of hydrogen for an atom of oxygen, benzoic acid is converted into the oil of bitter almonds, or the *hydruret of benzule*. This hydruret does not pre-exist in the bitter almonds, but is the result of the reaction of two organic principles contained therein, denominated amygdalin and emulsin, or synaptase, with water.

Benzule forms a compound with amide called *benzamide*.

Cinnamyle, $C_{18}H_8O_2$, has much analogy with benzule. It is the radical of the *oil* of *cinnamon*, and of a few other compounds.

Glyceryle, C_6H_7, the compound radical of *glycerine*, the hydrated oxide of glyceryle, which is the base common to many oils and fats. Glycerine will be more fully spoken of under the head of Oils.

Cetyle, $C_{32}H_{33}$, an organic radical, which performs precisely the same part in spermaceti that glyceryle does in ordinary fats.

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SECTION II.

ANALYSIS OF ORGANIC BODIES.

As all organic bodies undergo decomposition when exposed to a high temperature, in the presence of oxygen, this is the method adopted to effect their analysis; it is founded on the fact that the weight of the carbonic acid and water, resulting from the union of oxygen with the carbon and hydrogen of the organic body, will indicate the relative proportions of the latter elements. The following is an outline of Liebig's method, which is by far the most simple :— A tube of white Bohemian glass, called a *combustion-tube*, about a foot long, is drawn out at one extremity to a point, which is closed; the organic substance is mixed with the black oxide of copper (a substance which readily imparts oxygen when heated with an organic body), and the mass, being thoroughly dried and accurately weighed, is introduced into the tube. To this is attached another tube, containing dried chloride of calcium, to absorb the water that may form; this is also weighed. Lastly, to the end of the latter tube is attached an arrangement of glass bulbs containing solution of potassa, intended to absorb the carbonic acid that may be formed; this is likewise weighed.

Heat is now applied to the combustion-tube; decomposition of the organic body ensues; its carbon takes oxygen from the oxide of copper to form carbonic acid, every twenty-two grains of which contains six of carbon. The hydrogen of the organic body also takes oxygen to form water, every nine grains of which must contain one of hydrogen.

The result is then easily estimated, by a second weighing of the chloride of calcium tube, and the potash bulbs; the gain of the former indicating the amount of water, and *one-ninth of this gain expresses the quantity of hydrogen;*—the gain of the latter indicating the amount of carbonic acid, and six parts in twenty-two, or *three-elevenths of this, expresses the quantity of carbon.* Having thus ascertained the weight of carbon and of hydrogen, their sum, subtracted from the whole weight of the organic body, will give the weight of its oxygen.

If the body to be analyzed contains *nitrogen*, an alkali must be added to convert the nitrogen into ammonia, which is afterwards converted into chloride of ammonium by hydrochloric acid, next precipitated by bichloride of platinum, and then heated to drive off the chlorine and ammonium. The loss of weight gives the data for calculating the amount of nitrogen.

If *sulphur* is present, it is to be converted into sulphurous acid,

and then oxidized by nitric acid; the sulphuric acid is neutralized by baryta, and from this, the amount of sulphur can be calculated.

In organic analysis, the utmost precision is required in the processes of drying and weighing.

SECTION III.

VEGETABLE NON-AZOTIZED SUBSTANCES.

THESE embrace *Gum, Sugar, Fecula* or *Starch,* and *Lignin;* and, according to Prout, they may be considered as *hydrates of carbon,* since they contain hydrogen and oxygen in the proportions to form water.

GUM.

This is a proximate principle, which spontaneously exudes from various trees. It is distinguished from resin by being soluble in water and being insoluble in alcohol, and by the action of nitric acid, which converts it into *mucic acid.*

Guerin divides the gums into three classes :—1. *Arabin,* of which gum arabic is the type, soluble in cold water. 2. *Bassorin,* of which tragacanth is the type, which swells into a jelly, but does not dissolve in water. 3. *Cerasin,* from the gum of the cherry-tree; insoluble in cold, but soluble in hot water, by which it is partially converted into arabin.

The *mucilage* of gum arabic differs somewhat from the mucilage of flaxseed : the former is precipitated by the *subacetate* of lead; the latter by the neutral *acetate.*

Pectine, or the jelly of fruits, seems closely allied to the gums. It forms *pectic acid.*

SUGAR.

This is found in various saccharine natural juices, as of the Sugar Cane, the Maple, the Beet, &c. There are several varieties of sugar.

Cane sugar, $C_{24}H_{22}O_{22}$, prepared from the juice of the sugar-cane by boiling and evaporating; this constitutes *common brown sugar;* it is refined by dissolving in water, and removing the impurities by means of coagulating albumen. The uncrystallizable portion is named *molasses.* It is converted into grape-sugar by acids and a ferment.

Grape sugar, $C_{24}H_{28}O_{28}$, exists in many vegetable juices, especially in grapes. Examples of it are seen in candied sweetmeats, and in raisins; it also occurs in the urine, in diabetes. Grape sugar differs from cane sugar in several particulars : it is less sweet, less

soluble, and does not form such regular crystals. Strong mineral acids have but little effect on grape sugar; the alkalies, on the contrary, produce a decided effect. It is the only sugar capable of undergoing the vinous fermentation; the others being first converted into it.

The best *test* for grape sugar (as in diabetic urine) is to heat it with a little potassa and protosulphate of copper; a characteristic red precipitate occurs, consisting of the suboxide of copper.

Sugar of milk, *Lactine*, $C_{24}O_{24}H_{24}$;—this is the sweet principle of milk: it is procured by evaporating whey. It undergoes fermentation, like other sugars, but is believed to be converted into grape sugar in the process.

Mannite or *Manna sugar*, $C_6H_7O_6$;—this differs from other sugars in not undergoing the vinous fermentation. There is also a sugar from *mushrooms*, and one from *liquorice*.

FECULA, OR STARCH.

A very abundant proximate vegetable principle, abounding in roots, stems, and seeds. It is procured from flour or potatoes by the action of a stream of water upon them so as to wash off the insoluble particles of fecula.

Prop.—Insoluble in cold water, alcohol, or ether; appears to be a homogeneous substance, but if examined by the microscope, it is found to consist of granules, having a thin, insoluble envelope; when starch is put into hot water, the envelope bursts, liberating the contents, which form with the water a gelatinous mass. The most delicate *test* for starch is iodine, which forms with it a blue colour.

The size of the granules of fecula, as shown by the microscope, varies very much, according to the source from which it is derived. Arrow-root, sago, and tapioca, are examples of pure fecula.

In the process of the germination of seeds, and of the fermentation of malt, the starchy matter of the grain is converted into a sweetish, gummy matter, called *dextrine*, and ultimately into grape sugar. The cause of this remarkable change is due to a peculiar principle found resident in the grain at that period, named *diastase*, which acts by *catalysis*,—itself undergoing no change.

Dextrine has the same composition as starch. It is soluble in water. It is used in the arts as a substitute for gum. Sulphuric acid also has the power of converting starch into sugar. Nitric acid converts it into oxalic acid.

LIGNIN, OR CELLULOSE.

This constitutes the basis of vegetables and of wood. It is procured from sawdust by dissolving it successively in water, alcohol, ether, dilute acid, and an alkaline solution. It has no taste, but

may be converted into dextrine and grape sugar by the action of strong sulphuric acid. In its composition it is isomeric with starch.

SECTION IV.

PRODUCTS ARISING FROM CHEMICAL REACTIONS IN THE PRECEDING SUBSTANCES.

ACTION OF NITRIC ACID.

Oxalic Acid, C_2O_3, or $CO + CO_2$, is always formed by the action of strong nitric acid on any of the preceding bodies, except gum and sugar of milk. The oxygen of the acid acting upon the sugar, &c., converts it into oxalic acid, producing, at the same time, nitric oxide and water. It occurs in crystals, much resembling Epsom salts; of an intensely sour taste; soluble in water and alcohol; very poisonous. *Test,*—lime forms the insoluble oxalate of lime.

Pyroxylin, or *gun-cotton*, $C_{12}H_9O_9 + 2NO_5 + HO$;—prepared by the action of *strong* nitric acid on pure lignin, or cotton; the latter, apparently, undergoes no change, but becomes very explosive. Dissolved in ether, it constitutes *collodeon*, so much valued for its adhesive properties.

Xyloidine, $C_6H_4O_4 + NO_5$,—made by the action of nitric acid on paper. It resembles the preceding.

VINOUS FERMENTATION AND ITS PRODUCTS.

When a solution of sugar, in connexion with some ferment, as yeast, is subjected to a temperature of 70° to 80°, an intestine movement commences, denominated *fermentation;* bubbles of gas escape, the liquor becomes turbid; but after a while it becomes clear, when the sugar is found to have disappeared, and its place is occupied by alcohol. Such a liquid will yield *alcohol* by distillation. The gas which is generated and escapes is carbonic acid. The chemical change which is produced is the conversion of one atom of anhydrous grape sugar into two atoms of alcohol, and four atoms of carbonic acid.

Two atoms of alcohol, - - - - -	$C^8H^{12}O^4$
With four atoms of carbonic acid, - - -	$C^4 \quad O^8$
Form one atom of sugar, - - - -	$C^{12}H^{12}O^{12}$

In the process of fermentation, the yeast, or ferment, itself undergoes change, in which respect the action differs from that of *catalysis.*

The various kinds of fermented liquors, such as *wine, cider, beer,* &c., are made from the juices of different fruits, or from infusions of grain. These all contain sugar and a fermenting principle, and

hence will undergo the vinous fermentation, provided they be exposed to a proper temperature. The amount of alcohol contained in the fermented liquors varies from 3 to 20 per cent. By distilling any of the fermented liquors, the different *spirituous* liquors, or *ardent spirits*, are procured; these contain about fifty per cent. of alcohol; and by a second distillation, they yield the commercial alcohol, or *rectified spirit*, which has a density of ·835, and which yet contains about 14 per cent. of water.

Pure or *absolute* alcohol cannot be obtained by any number of distillations, unless quicklime, chloride of calcium, or sulphuric acid, be employed at the same time, to combine with the water.

Pure alcohol is colourless and limpid; has a sp. gr. of ·793; is inflammable, burning with a pale bluish flame, and yielding water and carbonic acid; boiling point, 173°; unites with water in all proportions; also with ether; has powerful solvent powers; it has never been frozen by the most intense cold.

The process of making bread is an instance of the vinous fermentation, the yeast added to the dough, converting a small portion of its sugar into carbonic acid and alcohol. The gas thus liberated, forces the tough and adhesive mass into bubbles; these still further expand by the heat of the oven, which at the same time dissipates the alcohol.

ACTION OF ACIDS ON ALCOHOL—ETHERIFICATION.

When alcohol is heated with any of the strong acids an *ether* results. The radical *ethyle*, C_4H_5, is the basis of all the alcohol series of ethers. This radical has lately been isolated. Common ether is an *oxide of ethyle*, C_4H_5O; and alcohol is a *hydrated oxide of ethyle*, $C_4H_5O + HO$. Consequently, the conversion of alcohol into ether only requires the removal of an atom of water. The rationale then of the action of sulphuric acid on alcohol, is merely to remove the water upon which the alcohol depended for its existence. There is hardly any acid from which a peculiar ether bearing its name has not been formed, such as *nitric ether, acetic ether, tartaric ether*, &c.

The oxide of ethyle, in consequence of being procured by the action of sulphuric acid on alcohol, was formerly called *sulphuric ether*, the name which it continues to bear in commerce; it is also frequently known by the simple name *ether*.

Prepared by boiling together equal weights of alcohol and sulphuric acid, and receiving the products in a vessel surrounded by ice. Various other substances are generated at the same time, such as sulphovinic acid, oil of wine, sulphurous acid, and others. The ether obtained may be mixed with a little caustic potash, and redistilled by a gentle heat.

Prop.—Pure ether is a colourless, transparent, fragrant liquid; sp. gr. about ·720; boils at 96°; very volatile and inflammable;

burns with a white flame, generating water and carbonic acid. Its vapour has a sp. gr. of 2·586. When mixed with oxygen, it explodes with violence, by means of an electric spark. When ether is transmitted through a red-hot tube, it is decomposed into olefiant gas, light carburetted hydrogen and aldehyde. It is very soluble in alcohol; but only one part is dissolved in ten of water. It may be separated from alcohol by the addition of water, which unites with the alcohol. It is a solvent for oils and fats generally; but its solvent powers are inferior to those of either alcohol or water.

Regarding ether to be a compound of ethyle with oxygen, or an *oxide of ethyle*, it is found that this oxide is capable of uniting with the oxacids, and forming with them compounds analogous to salts. All the halogen bodies, as chlorine, iodine, bromine, &c., unite directly with the radical of ether, just as they do with metallic radicals. The following are some of the ether-compounds:

Ethyle, - - - - - - -	C^4H^5
Oxide of ethyle, ether, - - -	C^4H^5O
Hydrate of the oxide, alcohol, - -	$C^4H^5O + HO$
Chloride of ethyle, - - -	$C^4H^5 + Cl$
Iodide of ethyle, - - - - -	$C^4H^5 + I$
Bromide of ethyle, - - -	$C^4H^5 + Br$
Nitrate of oxide of ethyle, - -	$C^4H^5O + NO^5$
Hyponitrite of oxide of ethyle, -	$C^5H^5O + NO^3$
Oxalate of oxide of ethyle, - -	$C^4H^5O + C^2O^3$, &c.

These compounds of ethyle and its oxide are obtained from alcohol—the hydrated oxide—by the action of the corresponding acids, as on an ordinary metallic oxide.

Hydrate of oxide of Ethyle, Alcohol.—This compound can only be obtained through the medium of the vinous fermentation. Its properties have already been described.

Chloride of ethyle, Hydrochloric Ether.—Prepared by the action of chlorohydric acid on alcohol, the product being collected in a cold receiver; or else alcohol may be added to the materials for generating the acid, viz. common salt and sulphuric acid. The rationale is precisely similar to that of the action of hydrochloric acid on a metallic oxide.

Prop.—A colourless, limpid liquid, very volatile, of a penetrating aromatic odour;—sp. gr. ·874; boils at 52°; soluble in ten parts of water.

Bromide of ethyle—Hydrobromic ether;—a very volatile liquid, heavier than water; of a penetrating odour and taste.

Iodide of ethyle, Hydriodic ether;—very closely resembles the last.

Sulphuret of ethyle;—a colourless liquid, of a disagreeable alliaceous odour; boils at 163°.

Cyanide of ethyle—resembles the last.

Acid Sulphate of oxide of ethyle—Sulphovinic acid, C_4H_5O,

$2SO_3 + HO.$—Sulphuric acid forms no *neutral* compound with the oxide of ethyle.* Sulphovinic acid is the *acid* sulphate of ethyle. It is formed by the action of strong sulphuric acid on alcohol, as in the preparation of ether; on cooling, it is diluted with water, and neutralized with chalk, which throws down sulphate of lime; the *sulphovinate of lime* is afterwards deposited in crystals: from this, sulphovinic acid may be obtained by the action of dilute sulphuric acid. It is a sour liquid, very apt to be decomposed into alcohol and sulphuric acid; forms *sulphovinates* with bases, which are soluble.

Phosphate of oxide of ethyle, or *Phosphovinic acid*, is a compound very analogous to the foregoing.

Nitrate of oxide of ethyle, Nitric ether.—This compound has only lately been prepared. It is formed by the action of nitric acid on alcohol, with the addition of urea; the latter substance being requisite, to prevent the formation of hyponitrous ether. It has a density of $1 \cdot 112$;—is insoluble in water;—has an agreeable sweet taste.

Hyponitrite of the oxide of ethyle, Hyponitrous ether, Nitrous ether.—This is best prepared, according to Liebig, by the action of hyponitrous acid, derived from nitric acid on starch, on alcohol, and condensing the product. A better method—that of Dr. Hare—is to act upon hyponitrite of soda by sulphuric acid and alcohol; the process being conducted in a refrigerated receiver. It is a pale, yellow liquid, very volatile, possessing an exceedingly agreeable odour and taste; boils at $62°$; sp. gr. $\cdot 947$. It is the active principle of *sweet spirits of nitre*, which consist of hyponitrous ether dissolved in alcohol.

In the same way we have *Carbonic Ether, Oxalic Ether, Acetic Ether, Formic Ether*, &c. &c.

ACTION OF OXYGEN ON ALCOHOL.

When alcohol is oxidized in the open air, that is burned, the products of the combustion are carbonic acid and water. But under peculiar conditions the alcohol may be *dehydrogenized*, i. e., deprived of its hydrogen only, leaving its carbon untouched. From such an action there result certain compounds having one common radical called *Acetyle*, C_4H_3. This differs from ethyle, the radical of ether, in containing two atoms less of hydrogen, and in forming compounds which are acids instead of bases.

The following are some of the acetyle compounds:

Acetyle,	C_4H_3
Hydrated oxide (Aldehyde),	$C_4H_3O + HO$
Hydrated binoxide (Aldehydic acid),	$C_4H_3O_2 + HO$
Hydrated tritoxide (Acetic acid),	$C_4H_3O_3 + HO$
Acetone,	C_4H_6O
Acetal,	$C_8H_9O_2$

* The *neutral* sulphate of the oxide of ethyle is stated to have been lately isolated.

Acetyle and its protoxide are alike hypothetical.

Aldehyde, Hydrated oxide of Acetyle, named from *alcohol dehydrogenatus,* is procured from alcohol or ether, by depriving them of two equivalents of hydrogen by means of oxygen. This is effected either by passing the vapour of alcohol through a red-hot tube; by putting a coil of fine platinum wire around the wick of a burning alcohol lamp; and best, by the action of chromic acid, alcohol being distilled with dilute sulphuric acid, and bichromate of potassa; the aldehyde is condensed in a cold receiver, and redistilled with chloride of calcium.

Prop.—A limpid, colourless liquid, having the odour of apples; boils at 72°; sp. gr. ·790. When heated with oxide of silver it causes a deposition of the latter in the metallic form, and is itself converted into aldehydic acid.

Aldehydic or *Acetylous Acid*—the hydrated binoxide of acetyle— is procured as just mentioned.

Acetic, or *Acetylic Acid*—the hydrated tritoxide of acetyle. If alcohol be presented to spongy platinum, the oxygen condensed into the pores of the latter reacts so powerfully upon the former as to cause its inflammation; but if diluted and slowly added, gradual combustion goes on, and acetic acid is evolved. It is also formed by the destructive distillation of wood. Various fermented liquids when exposed to the air become *sour,* that is, their alcohol unites with the oxygen of the air, giving rise to vinegar. The formula for alcohol is C_4H_6O+HO. If to this we add four atoms of oxygen, we have $C_4H_6O_2+4O$, which gives the formula of hydrated acetic acid, $=C_4H_3O_3$, $HO+2HO$.

The vinegar of commerce is chiefly made from wine or cider. The acid from wood is procured by distilling hard wood in close vessels: acetic acid is found among the products which come over; this requires redistillation and some subsequent treatment. This variety is termed *pyroligneous acid.*

The strongest acetic acid is prepared by distilling anhydrous acetate of soda with concentrated oil of vitriol. Crystals of hydrate of acetic acid are formed, which may be drained from the more fluid portion. At the temperature of 63° these crystals fuse into a limpid liquid, of a density of 1·063, possessing the pungent smell and taste of vinegar, and capable of blistering the skin. It is soluble to any extent in water and alcohol. Its vapour is inflammable. The water, which is essential to the constitution of acetic acid, is *basic,* and can only be replaced by some metallic oxide; *anhydrous* acetic acid, in a separate state, is unknown.

The *acetates* are all soluble salts; those of silver and mercury are least so. The most important acetates are the acetate and sub-acetate of lead, acetate of ammonia (spirit of Mindererus), and acetate of copper (verdegris).

Acetone, or *pyroacetic spirit*, is a volatile, colourless liquid, which is produced when any of the metallic acetates are subjected to a destructive distillation. It has a density of ·792, and boils at 132°; it is very inflammable, burning with a bright flame.

By distilling together acetate of potassa and arsenious acid, a substance is procured known as the *fuming liquor of Cadet*. This has been proved to be the oxide of a radical, which also has been isolated, named *Kakodyle*, C_4H_6As,—Symb. Kd.   It forms, like the other organic radicals, a large number of compounds, all of which are poisonous.

SECTION V.

SUBSTANCES RESEMBLING ALCOHOL.

In the distillation of wood, besides pyroligneous acid, there comes over an etherial body called *wood-spirit* or *wood-naphtha*.   There is a remarkable analogy between this substance and alcohol; like the latter, it is the hydrated oxide of a radical, which is termed *methyle*, whose oxide likewise is an ether.

The most important of the methyle series are the following :—

Methyle, - - - - -	C_2H_3, or Me.
Oxide, or Methylic Ether, - - -	C_2H_3O
Hydrated Oxide, or Methylic Alcohol, -	C_2H_3O+HO
Chloride of Methyle, - - - -	C_2H_3Cl
Sulphate of Oxide of Methyle, - -	$C_2H_3So_3$, &c.

Methyle has not yet been isolated.

Oxide of Methyle, Methylic Ether, is, like common ether, obtained by distilling together sulphuric acid and methylic alcohol.   It is a gaseous body, colourless, of an etherial odour, inflammable, partially soluble in water; freely soluble in alcohol, wood-spirit, and sulphuric acid; sp. gr. 1·617.   Its compounds are made precisely like the analogous compounds of the oxide of ethyle, only substituting methylic alcohol for common alcohol.

The analogy between the two above-mentioned radicals is still farther carried out in the action of oxygen.   By the oxidizement of alcohol we have formed acetic acid; so by the oxidizement of wood-spirit we obtain *formic acid, the hydrated tritoxide of formyle*,—formyle being a hypothetical radical expressed by C_2H.

Formic Acid, C_2HO_3+HO, so named because existing in ants, is obtained in an analogous manner to that employed for procuring aldehyde, only using wood-spirit instead of alcohol.

Prop.—A colourless liquid, of a penetrating odour; boils at 212°; solid at 32°.

No compounds of formyle have as yet been discovered corresponding to aldehyde and aldehydic acid.

Terchloride of Formyle, Chloroform, C_2HCl_3, made by the action of chloride of lime on alcohol, wood-spirit, or acetone, with the aid of heat. It is a thin, colourless liquid, of an agreeable odour, insoluble in water, but soluble in alcohol and ether; sp. gr. 1·49; boils at 141°; not inflammable.

There is still another alcohol, denominated the *amylic* alcohol, because procured by distilling amylaceous substances, as potatoes. It is sometimes called *potato oil.* It is *the hydrated oxide of Amyle,* another organic radical, and its formula is $C_{10}H_{11}O + HO$ (Amyle $= C_{10}H_{11}$).

Its *oxide,* or *amylic ether,* has been isolated, as well as many other of its compounds.

By oxidation, or dehydrogenation of amylic alcohol (as in the corresponding instances of ethylic and methylic alcohol), we obtain an acid—the *valerianic,* $C_{10}H_9O_3 + 2HO$; this is the hydrated tritoxide of a new radical not yet named, but expressed by $C_{10}H_9$. Valerianic acid is also procured by distilling Valerian root; and also from sugar of milk, by fermentation and a high heat.

SECTION VI.

VEGETABLE, OR ORGANIC ACIDS.

THESE acids are widely diffused throughout the vegetable kingdom. Many of them pre-exist in the plants; others are the products of the reaction of heat.

Acetic acid, $C_4H_3O_3 + HO$, has already been treated of.

Citric acid, $C_{12}H_5O_{11} + 3HO$.—This acid is found in the fruits of the genus *citrus,* including the lemon, sour orange, citron, and lime; also in several others, in combination with malic acid. It may be procured by saturating lemon juice with chalk, and then decomposing the citrate of lime by means of sulphuric acid. The citric acid crystallizes on evaporation. It forms colourless prismatic crystals, very soluble in water, of a very sour taste. The three atoms of water which it contains are essential to its constitution.

Malic acid, $C_5H_4O_8 + 2HO$, derives its name from the apple, in which fruit it largely exists. It may be procured by saturating apple-juice with lime, and decomposing the malate of lime by sulphuric acid. It is a deliquescent acid, without colour, and has an acid taste. It is bibasic.

Lactic acid, $C_6H_5O_5+HO$, derives its name from the word *lac,* the Latin for milk. It is the acid which exists in sour milk. It has lately been shown to be the product of a peculiar fermentation called *viscous,* by which the sugar of milk is converted into lactic acid. It is owing to the generation of this acid, that milk, when kept, becomes *curdled,*—the acid which is formed coagulating the casein. It is monobasic.

Tartaric acid, $C_8H_4O_{10}+2HO$.—This is the acid of grapes, tamarinds, and several other fruits, in which it exists combined with potassa. The tartaric acid of commerce is prepared from the *tartar* or *argol,* an impure acid tartrate of potash, which is deposited from the grape-juice during the process of fermentation. The argol, when purified, and deprived of its colour, constitutes *cream of tartar.* The acid is obtained from this salt by saturating it with carbonate of lime, by which it is converted into a tartrate of lime, and a tartrate of potassa; the latter is separated from the former, which is insoluble, by filtration; the tartrate of lime is then decomposed by sulphuric acid. It forms colourless, transparent crystals, freely soluble in water, of a sour taste. As it is bibasic, it requires two equivalents of a base to form with it a *neutral* salt; hence, the salts which it forms with a single atom of a fixed base, have an acid re-action, and require the presence of an atom of basic water. Thus, the salt heretofore known as bitartrate of potash (cream of tartar) must now be considered as an *acid tartrate of potash and water.* This salt forms small transparent crystals; it is tolerably soluble in boiling water, sparingly so in cold water; has an acid reaction and sour taste.

There is also a neutral tartrate of potash, called *soluble tartar,* which contains two equivalents of the base united to one of acid.

Tartrate of potash and soda,—Rochelle salts;—made by neutralizing a solution of cream of tartar with carbonate of soda. It forms large prismatic, transparent crystals, freely soluble in water. Acids precipitate cream of tartar from its solution.

Tartrate of antimony and potassa,—Tartar emetic;—made by boiling teroxide of antimony in a solution of cream of tartar; the basic water is displaced by the oxide. Tartar emetic crystallizes in octohedrons with a rhombic base; very soluble in boiling water; has an austere metallic taste. Its solution is decomposed by both acids and alkalies; the former throws down a mixture of cream of tartar and oxide of antimony; the latter, the oxide. Sulphuretted hydrogen precipitates the sulphuret of antimony.

Tartaric acid is distinguished by forming with any salt of potash the well-known cream of tartar.—Heat converts it into *pyrotartaric acid.*

Tannic acid, $C_{18}H_5O_9+3HO$. This is the astringent principle found in many vegetables, as the oak, gall-nut, &c.; it is generally

associated with gallic acid. It is best procured by pouring commercial sulphuric ether on coarsely-powdered galls, and allowing it to percolate slowly. The water, which always exists in combination with common ether, dissolves out the tannic acid, while the ether takes up the gallic acid and other matters; hence the liquid which has passed through will consist of two distinct strata, the lower one, which is a concentrated aqueous solution of tannic acid, and the upper etherial solution. The latter having been carefully removed, the tannic acid may be obtained by evaporation. It has a light-yellowish colour; of a porous, feathery texture; has a very astringent but not bitter taste; very soluble in water; less so in alcohol; insoluble in pure ether; has an acid reaction.

Tannic acid yields with the sesqui-salts of iron a deep bluish-black precipitate; it also precipitates the solution of tartar emetic, nitrate of silver, sulphate of copper, and acetate of lead; with gelatin it forms a dense whitish compound,—tannate of gelatin, the basis of leather.

The variety of tannin yielded by kino, catechu, and krameria, gives a *greenish*-black precipitate with the salts of iron.

Leather is made by soaking hides, which have been deprived of their hair, for a considerable time in an infusion of oak bark: the tannin which it contains combines with the gelatin of the skins.

Gallic acid, C_7HO_3+2HO, is usually found combined with tannic acid. It is believed to result from the action of the oxygen of the air upon tannic acid. It is not so soluble in water as tannic acid, nor does it precipitate gelatin, but it yields with sesqui-salts of iron a bluish-black compound.— *Writing ink* is a tanno-gallate of iron.

The remaining vegetable acids are of less importance; the most interesting of them are:

Oxalic acid, C_2O_3+HO, already alluded to.

Benzoic acid,—oxide of benzule,—exists in various balsams. It is best procured from gum benzoin by sublimation. It is in the form of white crystals, very light and feathery; exhales a fragrant odour, not due to the acid itself, but to some of the volatile oil; it forms *benzoates*.

Meconic acid,—exists in opium combined with morphia and codeia. It is characterized by forming a blood-red coloured compound with a sesqui-salt of iron.

SECTION VII.

THE VEGETABLE ALKALIES—VEGETO-ALKALIES.

THE vegeto-alkalies, or *alkaloids*, constitute a peculiar group of compounds. They are met with in various plants, always in com-

bination with an acid, which in many cases, is itself peculiar in its nature, not occurring elsewhere in the vegetable kingdom. They are generally insoluble in water, but dissolve in hot alcohol. Their taste in solution is usually intensely bitter, and their action on the animal economy very powerful, in consequence of which they are of the greatest value as medicines, containing, as they do, the most active properties of the plants in which they are respectively found. They all contain nitrogen, and are complicated in their constitution, having high combining numbers.

The number of these bodies is very large; only the most important will be here noticed.

Morphia, $C_{35}H_{20}O_6N + 2HO$,—the active principle of opium;—exists in it as a *meconate;* procured from an infusion of opium by means of ammonia, which throws down the morphia, leaving the meconate of ammonia in solution. It forms small shining crystals, which are colourless; nearly insoluble in water; soluble in hot alcohol; forms soluble salts with the acids, the most important of which are the *sulphate, muriate,* and *acetate.*

Narcotina, $C_{48}H_{24}O_{15}N$,—exists also in opium; it is separated from the other principles by boiling ether, which yields it on evaporation.

Codeia, $C_{35}H_{20}O_5N$—exists in opium as a *meconate;* forms colourless crystals; rather more soluble in water than morphia. Codeia forms salts with the acids.

Other principles found in opium are *Paramorphia* or *Thebain, Pseudomorphia,* and *Narceia;* besides *Meconic acid,* which has already been alluded to.

Quinia and *Cinchona*, $C_{20}H_{12}O_2N$ (Cinchonia, $C_{20}H_{12}ON$),—the active principles of Peruvian bark;—exist in it in combination with *kinic acid;* procured from an infusion of bark by the action of quicklime, which combines with the kinic acid, liberating the alkalies; these are then to be taken up by boiling alcohol, and decolorized by animal charcoal.

Quinia occurs as a whitish powder; it does not crystallize. Cinchona is in the form of minute crystals. Both are very insoluble in water, but dissolve in boiling alcohol. Their most important salts are the *sulphates,* which are soluble in water.

Strychnia and *Brucia*, $C_{44}H_{23}O_8N_2$ (Brucia, $C_{44}H_{25}O_7N_2$), alkalies existing in the Strychnos nux vomica, St. Ignatius' bean, and false Angustura bark: they are associated with *igasuric acid.*

Veratria, $C_{34}H_{22}O_6N$, the alkaline active principle of the *Veratrum sabadilla,* and of the *Veratrum album,* or white hellebore.

Emetia is the alkaline principle of ipecacuanha. *Colchicina,*—the active principle of the *Colchicum autumnale. Solania,*—the alkali of the *Solanum dulcamara. Caffeia,* or *Theine,*—the active alkaline principle found both in coffee and tea.

We have also *Atropia*, from belladonna; *Aconitia*, or *Aconitine*, from aconite; *Daturia*, from stramonium; *Coneia*, from hemlock; *Nicotina*, from tobacco, &c., &c.

Besides the foregoing vegetable alkaline principles, there exist a number of *neutral* principles in plants, possessed of very active properties. Some contain nitrogen, and some do not. The most important of them are *Phloridzin, Salicin, Asparagin, Gentianin, Elaterin, Cathartin, Quassin, Lupulin, Ergotin,* &c., &c.

SECTION VIII.

AZOTIZED VEGETABLE SUBSTANCES.

THESE include *Gluten, Vegetable albumen, Vegetable fibrin,* and *Vegetable casein,* or *Legumen.* They are sometimes called *vegeto-animal* principles, from their strong analogy with similar principles found in animals.

Gluten.—It owes its name to its adhesive property: to it is due the adhesiveness of wheat-dough. It exists chiefly in the seeds of plants, in combination with starch;—may be separated by washing away the starch from wheat flour. It is almost insoluble in water, but soluble in alcohol; gluey when moist, but yellow and translucent when dry. It is a highly nutritious substance. It is owing to it that the rising of wheaten bread is due; the carbonic acid which is formed by the fermentation of the yeast being entangled in the meshes of the gluten, and thereby imparting the cellular structure to the loaf.

Vegetable albumen, Vegetable fibrin, and *Vegetable casein* also exist in vegetables in combination with gluten. Vegetable albumen is coagulated by heat; vegetable casein is coagulated by acetic acid. The chemical composition of all these principles is nearly, if not quite identical, being $C_{54}H_7N_{15}O_{21}$, with some sulphur.

SECTION IX.

OILS AND FATS.

OILS are divided into two classes, *fixed* and *volatile;* the former produce a greasy stain upon paper, which is permanent under the action of heat; the stain produced by the latter is removed by heat. There is no essential difference between oils and fats; the chief distinction is in their different degrees of consistency. All of them have more or less attraction for oxygen; some of them to such an extent as to produce spontaneous combustion of light sub-

stances moistened with them; this is very apt to be the case with *linseed oil*. From this results the division of fixed oils into drying and non-drying. The oils used in painting belong to the first class.

The parts of vegetables which contain most oil are the seeds; olive oil is obtained from the fruit itself.

The fixed oils have but slight odour or taste; whenever these qualities are found in a fixed oil, they are due to a volatile principle associated with it, as in the case of butter. They are all insoluble in water, but slightly soluble in alcohol, with the exception of castor oil, but soluble in ether and in volatile oils.

Although oils appear to be homogeneous, they in reality consist of several proximate principles. Of these, the most solid one in animal oils is called *stearin*; in vegetable oils, *margarin*; the most liquid in both is named *olein*, or *elain*. These principles may easily be isolated by submitting the whole to boiling alcohol, which, on cooling, deposits the margarine and stearine, but retains the olein. The margarine may be then separated from the stearine by ether, and the olein from the alcohol by distillation. These three principles consist respectively of an acid, united with a base. The acid is named *oleic*, *stearic*, and *margaric*; the base is the same for each; it is called *glycerine*.

When any of the fixed oils or fats is mixed with an alkali, a change takes place denominated *saponification*, resulting in the formation of a *soap*; the several acids just mentioned quit the glycerine with which they were united, and combine with the alkali. Thus common soap, made by the action of potassa on fat, consists chiefly of a stearate of potassa. If a soap be decomposed by an acid, the particular fat acid of which the soap may have been constituted will be precipitated. The formation of the lead plaster is a true instance of saponification, the oleo-margarate of lead being formed, and the glycerine remaining in solution.

Spermaceti.—This substance is found in the cranium of a certain species of whale, in union with an oil. It has a crystalline structure, melts at 120°, is soluble to some extent in boiling alcohol, also in ether. It is saponified with difficulty, two substances resulting, called *ethal* and *ethalic acid*.

Wax.—This substance, whether procured from the bee, or from the pollen and leaves of flowers, is found to consist of two distinct principles termed *cerine* and *myricine*; these principles may be separated by boiling alcohol.

All the fixed oils are compounds of carbon, oxygen, and hydrogen.

Volatile Oils.—These are very numerous, and impart the peculiar odours to plants. They are procured from the various parts of plants by distillation with water, common salt being sometimes added to elevate the boiling point.

When pure, they are colourless, but they generally have a slight tinge; they have a powerful odour and strong taste; do not saponify; absorb oxygen when exposed to the air; are freely miscible with the fixed oils; are very slightly soluble in water; freely so in alcohol and ether. They consist of two proximate principles, analogous to those of the fixed oils, and named *stearoptin* and *eleaoptin*.

Some of the volatile oils consist solely of carbon and hydrogen, as the *oil of turpentine*; others of carbon, hydrogen, and oxygen; and a few contain sulphur, as the oils of mustard, horseradish, &c.

Camphor is a solid volatile oil, having all the characters of the essential oils.

RESINS.—These are generally found in vegetables associated with some volatile oil. Common rosin affords a good example; it is procured from turpentine, which is a compound of rosin and the volatile oil of turpentine. When turpentine is distilled, the oil passes off, leaving the rosin behind.

Resins are insoluble in water, but soluble in alcohol, and in volatile and fixed oils; they are inflammable, and yield on distillation carburetted hydrogen, and several other products; a moderate degree of heat imparts an adhesive quality to them. Some resins resemble fixed oils, in containing two principles, one being more soluble in alcohol than the other. Resins are also susceptible of saponification. Concentrated nitric acid acts upon resins with an explosive violence.

The most important resins, besides *rosin*, are *lac, copal, mastic*, and *dragon's blood*.

Amber is a fossil resin.

Caoutchouc, or *India rubber*, is an exudation from a tree, resembling both the volatile oils and the resins. It is peculiar in being *elastic*.

Gutta Percha is a concrete juice from a tree growing in Borneo. It resembles caoutchouc in many respects.

BALSAMS.—This term is properly used to express a native compound of resin, volatile oil, and benzoic acid, as in the balsams of Tolu and Peru. The name is also improperly given to compounds of resins and volatile oils, as copaiva.

The term *Gum-resins* is applied to a class of vegetable substances, consisting of a mixture of gum and resin, with some other principles: they comprise some of the most valuable medicines, as *opium, gamboge, ammoniac, assafœtida, myrrh, scammony*, &c.

SECTION X.

ANIMAL COMPOUNDS.

Protein and its compounds.—The most important protein compounds are *Albumen, Fibrin*, and *Casein*.

Albumen exists in eggs and the serum of the blood,—being combined in the latter with soda: the white of an egg affords a good example of it. It is not soluble in water, unless a little alkali be present; coagulates by heat, acids, creasote, alcohol, and electricity; it gives precipitates with most of the metallic salts, particularly *corrosive sublimate*, for which it is the best antidote.

It is composed of carbon, oxygen, hydrogen, nitrogen, sulphur, and phosphorus;—or supposing *protein* to be represented by Pr, the formula for albumen would be, $Pr + P + S_2$.

Fibrin constitutes the chief portion of muscular flesh; it is also an important constituent of the blood, in which it exists in the soluble state. It may be procured either from muscle, or preferably, by whipping freshly-drawn blood with a twig; the fibrin adheres to it in long white filaments. Its characteristic is its spontaneous coagulation; it is in consequence of this tendency that blood coagulates when drawn from the body. Its composition is very nearly identical with that of albumen,—containing one equivalent less of sulphur. Albumen is converted into fibrin, in the living body, in the process of organization. Its proportion in the blood is liable to variation by disease.

Casein is found in milk, and is the basis of cheese. It closely resembles albumen, but differs from it in not being coagulable by heat. In composition it is nearly identical with the two foregoing substances, but it contains no phosphorus.

From either of the above three compounds, protein may be procured, by dissolving them in an alkaline solution, and then precipitating by an acid.

Gelatin and Chondrin.—These principles constitute the bases of skins, tendons, cartilage, and fibro-cartilage, &c. Any of these, when boiled for a long time in water, yield a jelly, which, on cooling, solidifies into *gelatin* or *glue*. *Isinglass* is the dried swimming-bladder of the sturgeon. *Chondrin* is very analogous to gelatin; it is procured in the same manner, from *cartilage*. Both are soluble in hot water. Gelatin is characterized by giving a precipitate with tannic acid,—*tannate of gelatin*.

The different solids and fluids of the body all contain various interesting principles, as for example, *blood, urine, chyle, bile, bones, nerve-substance*, &c.; but the space here allowed will not permit an examination of them. In fact, they more properly come under the division of PHYSIOLOGY, to which the student is referred for an account of them.

THE END.